JOURNAL OF ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

NOVEMBER

1950

Volume 9 Number 4

CONTENTS

	Page
Problems, Techniques, and Experimental Designs in Animal Investigations, A Symposium	461
The B-Vitamins in Relation to a Cobalt Deficiency in Sheep, W. H. Hale, A. L. Pope, P. H. Phillips and G. Bohstedt	484
Alfalfa and Alfalfa-Brome Grass Hays for Growing and Fattening Lambs, T. B. Keith, Russell H. Stark and C. W. Hickman	491
The Feeding Value of Norghum Sorghum When Fed to Lambs, R. M. Jordan	495
The Use of Progesterone in the Synchronization of the Estrual Periods in a Group of Ewes and the Effect on Their Subsequent Lambing Records, C. C. O'Mary, A. L. Pope and L. E. Casida	499
The Magnitude of Certain Sources of Variability in Digestibility Data, Burch H. Schneider and Henry L. Lucas	504
Cellulose Digestion in Good and Poor Quality Roughages using an Artificial Rumen, Wise Burroughs, H. G. Headley, R. M. Bethke and Paul Gerlaugh	513
Cellulose Digestion by Rumen Microorganisms as Influenced by Cereal Grains and Protein-Rich Feeds Commonly Fed to Cattle using an Artificial Rumen, Wise Burroughs, John Long, Paul Gerlaugh and R. M. Bethke	523
Some Effects of Forage Composition on Its Nutritive Value When Cut and Fed Green to Steers and Wethers, as Determined Conventionally and by the Lignin Ratio, R. M. Forbes and W. P. Garrigus	531
The Sulfur Dioxide Preservation of Grass Silage, C. B. Knodt	540
Effect of Ration upon Some Constituents of Blood and Milk of Hereford Cows and the Blood of Their Calves, W. J. Van Arsdell, O. B. Ross and R. W. MacVicar	545
Deposition and Alimentary Excretion of Phosphorus-32 in Steers on High Molybdenum and Copper Diets, Ray L. Shirley, Riley Deal Owens and George K. Davis	552
The Influence of Solvent Extracted and Hydraulic Processed Cottonseed Meals upon Performance and Level of Plasma Carotene, Vitamin A, and Fat in the Blood of Wintering Beef Cows, A. P. Parham, R. W. Colby and J. K. Riggs	560
Simplified Methods and Equipment Used in Separation of Urine from Feces Eliminated by Heifers and by Steers, C. S. Hobbs, Sam L. Hansard and E. R. Barrick	565
The Influence of Feeding Thiouracil to Dairy Bull Calves, A. B. Schultze, I. L. Hathaway and W. J. Loeffel	571
The Hereditary Aspect of Eye Cancer in Hereford Cattle, R. R. Woodward and Bradford Knapp, Jr.	578
Revised Estimates of Heritability of Economic Characteristics in Beef Cattle, Bradford Knapp, Jr. and R. T. Clark	582
The Repeatability of Performance of Several Hereford Sires as Measured by Progeny Records, R. R. Woodward and R. T. Clark	588
Causes of Variation in Length of Gestation in Dairy Cattle, S. M. Jafar, A. B. Chapman and L. E. Casida	593
The Effect of the Plane of Nutrition on the Carcass Quality of a Line of Swine Based on a Chester White and Danish Landrace Cross, H. H. Brugman	602
Dried Whole Aureomycin Mash and Meat and Bone Scraps for Growing-Fattening Swine, K. C. Lepley, D. V. Catron and C. C. Culbertson	608
Effect of APF Supplement on Efficiency of Feed Utilization for the Pig, T. J. Cunha, J. E. Burnside, G. B. Meadows, H. M. Edwards, R. H. Benson, A. M. Pearson and R. S. Glasscock	615
Inadequacy of Purified Diets for Reproduction by Swine with Observations on an Added Deficiency of Pantothenic Acid, H. W. Hodgskiss, M. E. Ensminger, R. W. Colby and T. J. Cunha	619
Comparison of High and Low Protein Corn for Growing-Fattening Pigs in Drylot, F. A. Dobbins, J. L. Krider, T. S. Hamilton, E. B. Earley and S. W. Terrill	625
Abstracts of Papers to Be Presented at 1950 Annual Meeting of the Society	634
News and Notes	685
Subject Index	687
Author Index	693

PROBLEMS, TECHNIQUES, AND EXPERIMENTAL DESIGNS IN ANIMAL INVESTIGATIONS

A Symposium Presented at the 1949 Meeting of the American Society of Animal Production

Introduction

The Committee on Investigations: W. M. Beeson, L. J. Bratzler, G. E. Dickerson (Chairman), C. W. Kincaid, C. E. Terrill

PRODUCTIVE research requires selection of significant problems, development of appropriate techniques and use of efficient experimental designs. In attempting to serve the Society, the Committee on Investigations felt that our collective research effort would benefit from a Symposium discussion of the problems most urgently in need of solution in animal production, and of the experimental and analytical techniques and designs offering most promise for attacking these problems. One objective of this Symposium is to help all of us obtain a better perspective in our research work and thus make our efforts more effective. We did not have in mind a presentation of detailed techniques, but rather an evaluation of problems and experimental approaches, the details of which individuals can "ferret out" if convinced that it is worthwhile to do so.

The Committee has invited four well qualified members of the Society to focus our attention on important problems and promising methods for attacking them. The presentations are divided into the four major areas of Nutrition and Pastures, Meat Evaluation and Processing, Physiology, and Breeding and Genetics. However, the overlapping and interdependence of these special fields is clearly evident and, for this reason, all are presented in a single Symposium rather than in the separate sectional programs. The speakers were encouraged to solicit suggestions from other workers in their respective fields.

The present publication is intended to serve as a reference and reminder to those who attended the Symposium and as a stimulus to workers who were not present. The Committee feels that it speaks for the Society in expressing our genuine appreciation to the Symposium speakers for their thought-provoking efforts.

Nutrition and Pasture

E. W. CRAMPTON
Macdonald College (McGill University)

ONE of the by-products of a Conference of Agricultural Specialists held in Australia during the late summer of 1949 was a Resolution reading in part as follows: " . . . It is recommended that research be intensified seeking a method of feed description from which useful estimates of digestible energy and digestible protein content may be made without the necessity for actual digestion trials on specific samples of feedstuffs": and " . . . research is urgently required to determine methods which will enable the estimation of the intake and digestibility of nutrients by grazing animals without the usual digestibility trial using collected pasture samples."

These suggestions are thought provoking. In the first place they imply that a knowledge of the extent to which a feed or ration is digested by an animal is of major importance in a description of its useful energy and, within certain limits, of its useful protein. Certainly incomplete digestion represents the most variable and often the largest loss to the animal of the potential energy of the ration. If the extent of digestion of a nutrient, or of the potential energy of a ration, is found to be correlated with some easily determined chemical or physical characteristics of the feed, the problem of feed description in terms indicating nutritional value will be much facilitated.

However, the problem is complicated by the uncertainty of the associative effects of feeds. Indeed, we are faced with the question of the extent to which digestion coefficients are biological constants, though the assumption that the digestible nutrients of individual feeds are practical constants has been implicit in much of the description of feeds appearing in tables within recent years.

There is a special problem of digestibility in the case of pasture herbage where intake is difficult to determine, either qualitatively or quantitatively; and where quantitative feces collection is a decidedly troublesome matter. If it should be shown that the variations in the output of fecal nitrogen are largely traceable to dry matter intake (as might be the case where the digestibility of the dietary protein is practically constant), then a nitrogen and a chromium determination on a "grab" sample of feces from a grazing cow, fed a constant quantity daily of chromium (or other index substance) may permit estimation of both dry matter intake and of dry matter output. Obviously perfection of some such scheme would be of much immediate and direct value. The advantages of such modifications in the techniques of determining digestibility are to be found partly in the freedom from artificial conditions of digestion crates and feces collection harness.

It may be worth pointing out also that Conference discussions concerning the usefulness of present feeding standards for cattle and sheep brought to light that Australian and New Zealand workers have found modern standards to be at least 25% too low in the recommended energy allowances. This may, in part, be due to the failure of present standards to include in their estimates figures for non-productive maintenance; for example, the energy cost of the walking of grazing animals. Standards used in North America have been applied primarily to stalled animals. However, it is evident that the energy cost of gathering feed is a considerable item. It would seem that research could well be instigated or continued on the energy costs of activity of animals with a view to amplifying the information now contained in modern feeding standards.

It is hardly necessary specifically to mention research in the field of vitamins or of minerals, other, perhaps, than to suggest that if one part of this work is more urgent than another, it is that of identifying sub-clinical states of deficiency, since it is in these early stages that correction can most often be expected to be successful. A clarification of the inter-relationship between vitamins, micro elements, and other nutrients with respect to requirement levels is also needed.

Techniques suitable for research in nutrition have been refined and greatly expanded during recent years. It would be presumptuous to attempt to summarize acceptable techniques since these will vary with the problem, and, above all, with the ingenuity of the researcher. Methods of the physicist, bacteriologist, pharmacologist and physiologist are all being added to those of the chemist and animal husbandman. Among the newer techniques, the use of radio active isotopes appears to offer attractive possibilities.

It may be pertinent, at this point, to comment on one or two changes which are noticeable in this field. It seems certain that the old stand-by of the earlier days, the unadorned comparative feeding trial, will give way to procedures giving more precise answers. Often the feeding trial will be the basis for a variety of supplementary tests or experimental treatments which, when superimposed on the main comparisons, will greatly enhance the amount and usefulness of the information obtainable from the experiment.

Such changes or developments bring with them other requirements, not the least of which is the necessity of a careful design for any test,—this design to be settled, including the methods by which the data are to be examined, before the test actually gets underway.

The use of statistical methods in the interpretation of nutrition experiments has gone the usual course of most new developments. In the early stages statistics as such were far too much in evidence in the reports of

nutrition studies; and the procedures employed often did not go beyond measures of variation and tests of significance. Following this early phase more complicated analyses were in evidence, sometimes of data from trials which did not warrant the treatments. More recently greater emphasis has been placed on the design of trials with a view to assuring that the data will be interpretable regardless of what method of analysis may actually be employed.

In this connection there have been comments by many research workers indicating that they would prefer to return to the simple design of trial. On the other hand, those taken with the possibilities of statistical procedures argue that the more complicated and comprehensive trials are usually more efficient and actually lead to better information than do the more restricted tests. Perhaps both schools are correct, the difference being that no particular design is best for all types of trials. It seems fair to point out, however, that data obtained from trials which cover a very restricted field of observation may not be as suitable for generalizations as are data from trials which include a wider variety of conditions under which the data are collected.

While the primary purpose of this paper is to introduce and provoke discussion on problems and techniques in nutrition and pasture experimentation, it may be in order to suggest in outline a pattern experimental design with which we have had some experience and which we feel meets many of the requirements for a type of feeding test employed in the study of a whole host of nutritional problems. For example, we might be interested in a test in which a comparison is to be made of male vs. female, hand vs. self feeding and of the effects of the addition to a ration of wheat bran at different levels upon the growth rate of bacon pigs and the character of their carcasses.

In this test three ration differences will be involved: viz, the test ration which contains no bran, the test ration diluted with 25% of its weight as bran, and the test ration diluted to half its weight with bran. Half the pigs in the test will be hand-fed and half self-fed, and within each of these groups half the pigs will be male and half female on each of the three ration treatments. This pattern could, of course, be extended to include, for example, replicates during different seasons; or the ration treatments could be increased in number depending on the extent of facilities which may be available; and other or additional cross treatments be introduced as desired. From the standpoint of ease and rapidity of calculation, as well as maximum detailed information, the variance is broken down to single degrees of freedom.

It is not the purpose of this paper to discuss statistical procedures.

Those who are interested in the detail of the problem will, of course, be able to obtain information which is desired from appropriate publications. I merely wish to point out at this time that the example given above, not only gives specific information on the effects of adding two different levels of bran to a particular ration, but it yields as well information as to whether the effects of the bran additions will be the same under hand or self-feeding, and whether males and females will respond similarly to such treatments. Thus generalizations can be made from experiments of this type with much more confidence than it is possible to do where the test is confined to one set of conditions. This, it seems to me, is an advantage which should not be underestimated in the matter of experimental designs of trials in nutrition.

There are, of course, many ramifications of the use of statistics in ferreting out all of the information which the data from any given experiment contains. To this end the analysis is often justifiably carried through simple, partial and multiple correlation and regression. There is frequently a surprising amount of sound information which may lie hidden in data from comparative feeding tests and entirely missed if only the superficial examination of the data by means of averages and feed gain ratios is made.

I shall draw again on experience from our laboratory to illustrate a case in point. In a study of certain oils intended for use as shortenings we had demonstrated that there was damage to their nutritive value following heating. We had also learned that additions of either yeast or of sheep feces would partially alleviate the harmful effect of the heat. These substances, however, had a somewhat beneficial effect on the control diet. To obtain further information we designed a test in which heated vs. unheated oils were employed as the major comparison. In each of these sections, one-third of the animals received a yeast supplement; one-third sheep feces (to 25% of the diet); and the remaining third were controls. After the first 28 days the animals were reallocated—half those on the control (nil) groups now received a yeast supplement and the others sheep feces. Similarly those originally on yeast now were divided between nil and feces; and the original feces group divided between nil and yeast.

When the gain and feed data were examined, no correlation was found between these two variables. Here was a warning that something was wrong, and it would have been foolish to have accepted the statistics and concluded that the gains were not related to feed intake.

A little thought made it clear that the trouble might be due to the feces-containing diet. In all probability the feces were not digestible—they had been voided once as "non-digestible" by the sheep. Adjustment of the gains for *digestible* Calories consumed brought all gains into explainable relation excepting those in the second part of the test.

Closer examination of the data showed that the uniformity of the initial weights of the animals at the start of the second period had been considerably disturbed by the differences in the diets in period one. By employing partial regression it was possible to 'eliminate' the general effects of differences in size of the animals as they started the second period and to arrive at an estimate of gain for the groups which showed a clear cut quantitative picture of the effects of heating the oils and of the preventive and curative effects of yeast or of feces.

A warning should be sounded, however, as to the danger of becoming intrigued with the intricacies of statistics to the detriment of sound data interpretation. It may be in order to emphasize the point brought out many years ago by Dr. R. A. Fisher, the father of much of the statistics of small numbers, to the effect that "if the statistics do not agree with the biology, suspect the statistics." This implies that the person best qualified to interpret data from nutrition studies is one who knows the biology involved as well as the manipulations of the statistical tool which he may have chosen to use.

Frequently it turns out that the investigator must decide against some detail of the statistical result in favor of a conclusion which is sound biologically. This does not mean that if the statistics do not agree with some preconceived idea as to what the results should be that we should disregard the statistics; but it does mean that it is entirely possible to find, mathematically, spurious correlations which have neither explanation nor justification biologically; and these investigators must be ever alert to recognize in order to avoid the pitfalls of conclusions based on them.

The relative place of statistics in experimentation requires consideration also from the standpoint of reports intended for publication. There are those who would refuse for publication any papers in which the variability of the data of groups has not been determined and considered in the interpretation. I believe there is much to be said for this stand. On the other hand, it should be kept in mind that statistics is only an analytical and descriptive device at the disposal of the researcher. Unless it is primarily concerned with method it is doubtful if the report of an experiment should include any obvious exhibition of a shiny tool, regardless of whether that tool has become polished from long diligent use, or because it has not yet had its newness worn off.

In conclusion I should like to make a plea for a more realistic use of data tables in the published reports of nutrition experiments. I am reminded of the story of the absent minded instructor who, in demonstrating the use of the slide-rule, found that 9 divided by 3 was 2.9999,—"well call it 3." The question of how many digits are statistically significant in any number

is one which is easily established mathematically. The number of digits in a figure which are of practical significance is quite another matter. For example, it may be possible to show mathematically that digestion coefficients have been determined in an experiment with an accuracy which warrants three decimal places in the percentage figure. It seems doubtful, however, whether in most published reports there is any practical call for reporting digestibility coefficients with any decimal places.

The question is not one of indicating how accurately the experiment was done, but rather the accuracy which may be implied in digestion coefficients as indices of food utilization. Digestion coefficients do not show a reproducibility even on the same animal which will warrant their being reported as fractions of a percent. Thus the problem of practical vs. statistical accuracy is a problem in the clarity and simplicity of tabular material used to illustrate the results of experimental findings. I suggest in the interests of ease of interpretation and reasonableness of publication costs that most data tables should be reported in terms of practical significance, even though this necessitates rounding figures quite beyond what their statistical significance would indicate is necessary.

Meat Evaluation and Processing

D. E. BRADY
University of Missouri

AT THE suggestion of the Committee on Investigations a questionnaire was directed to those engaged in meat work at our various Colleges and Universities as well as the Bureau of Animal Industry to ascertain their views on Meat Evaluation and Processing as related to Problems, Techniques and Experimental Designs in Animal Investigations. A total of 24 replies was received. I wish to express my apreciation to those who made the various comments and suggestions which are incorporated in this paper.

Our primary interest in meats is concerned with the better feeding of the 148 million people in this country. With an increased appreciation of the importance of soil conservation more thought is being given to the quality of meat which can be produced by the maximum use of pasture and roughage feeds. Thus, our objective is the production of good quality lean meat of the intermediate grades. While there will continue to be beef produced for the luxury trade requiring a large amount of fat covering, and while we may not feel that this type of beef production is economical, the principal problem is largely that of explaining that the highest grade does not necessarily indicate the greatest consumer preference. Beef of this quality probably needs less attention than beef at the lower end of the

scale. Not only are there likely to be more roughage and pasture fed cattle but as our population increases there will be a larger supply of meat from discarded dairy cattle. This class of livestock offers great opportunity, through processing, for changing a low quality product to one that meets with a high degree of consumer acceptance.

It is necessary to give greater consideration to the improvement of livestock through an overall integrated effort. Thus, we must strive for increased cooperation between fields of Genetics, Physiology, Nutrition, Production and Meat Evaluation. The meats laboratory must cooperate in evaluating the results of Animal Husbandry research when the end product, meat, is concerned, but it is the joint responsibility of all to seek improved methods of estimating the value of the end product. To do this better criteria are needed. The determination of grade, dressing percentage and cut-out yields are of value. They need, however, to be supplemented with improved means of objective evaluation. Meat research is no longer the simple though somewhat tedious task of slaughter, cutting, and gross evaluation. It is an unrelenting searching for the truths of "what," "how," and "why." This in turn necessitates the help of the chemist—both the analytical and the physical, the histologist, physiologist and the bacteriologist. Many of the factors which are of concern in studies of evaluation are also pertinent to meat processing studies. More knowledge is needed on factors affecting tenderness, flavor, juiciness, color and food value, of the changes that go on during rigor, chilling, aging, freezing, curing, and storing. There are also many questions unanswered concerning variable, optimal and minimal nutritional levels in their effect on the growth, fattening, and the quality of meat produced.

A considerable amount of pork carcass evaluation work has been done by workers of the U. S. Department of Agriculture and the State Experiment Stations. Relationships between back fat thickness, length, weight and yield of preferred cuts have been determined. From these studies it has been possible to arrive at certain standards; for example, the thickness of back fat is used to classify carcasses as to their yield of fat and lean cuts. There appears to be a need for certain corrections to some of the simple carcass measurement evaluations to secure even greater improvement.

Some of our meats people are of the opinion that possibly undue emphasis is being placed on cut-out values when compared with the emphasis being placed on consumer acceptance values. It has also been noted that beef carcasses of obviously poor conformation may show little differences in the percentage of desirable cuts when compared with carcasses of obviously good conformation. This may be true since the thinness of good cuts may also be found in other less desirable cuts. It has been suggested that there

may be value in setting up certain optimal standards for beef carcasses and cuts by age. It would thus be possible to make improved comparisons of cut-out yield from cattle produced under varying experimental conditions.

More information is needed on the amount and character of finish necessary to produce meat of desired and acceptable qualities. These are not simple tasks and support is necessary if the objectives are to be attained. Problems for which answers are needed also include:

1. How to identify and measure differences in the quality of meat, differences which may be the result of various feeding and breeding practices?
2. What changes occur during certain processes such as curing and smoking?
3. What factors affect the color of meats in the fresh, pre-packaged and frozen conditions?
4. What are the effects of temperature, humidity, rate of air-flow, temperature differentials, as well as oxygen and moisture barriers on the quality of fresh, cured and frozen products?

These problems indicate the desirability of a broad field of cooperative and specialized effort to find the answers. There appears to be little justification for meat research in land grant institutions continuing along present restricted lines. There is no intent, however, to leave the impression that the meats man cannot alone carry on certain projects of value. The meats man who receives adequate training in chemistry, physiology, bacteriology and the other related sciences is far better prepared than otherwise to seek answers to the problems. He is unusual, however, if he is well trained and experienced in each of these fields, including statistics. This is all the more true if he is expected to teach two or three courses each term. The problems requiring but simple techniques and methods of approach have largely been answered. Solutions to problems which we now face will be found only if the best efforts of the scientifically trained meats men are teamed with others well trained in basic science who are competent in helping to develop new and improved techniques.

This means greater cooperation within our own departments, and branches out to other departments for specialized assistance. That we have lacked closer cooperation in our work is due in part to the preoccupation by the researcher in problems of his own special interest rather than any intent of non-cooperation. The result is often failure, however, to utilize funds, facilities and personnel to attack the problem more effectively. This tendency is found to an even greater extent in inter-institutional relationships.

In pointing out the complexities of specific problems it would be amiss if some attention were not given to a more fundamental consideration. This is the failure of some leaders in Animal Husbandry to be very greatly concerned as to the wishes of the meat consuming public. As a consequence considerably less emphasis has been placed on problems of meat evaluation and processing than on production problems. Answers to these problems usually have been considered to be either the sole responsibility of the meat packers and retailers or, if our responsibility, too difficult to attack. If we can agree that our responsibility in agricultural research lies not only with the producer but also with the consuming public we will have done much to create a favorable environment for more adequate meat research.

Suggestions have been made by meats people at a number of Institutions as to the need for an overall cooperative research program in meats. Interestingly enough, this expression has come from institutions which are the best equipped by way of staff and facilities to proceed on their own.

At present there are but few meats men in the various Colleges and Universities who participated in the work of the Committee on Cooperative Meat Investigations. This Committee was organized about 25 years ago in connection with the Purnell "Quality of Meat Studies." A great amount of credit is due those who were responsible for initiating and carrying on this program. For example, the five volumes of abstracts prepared by the Review Committee assisted by the National Live Stock and Meat Board (1937, 1937, 1942, 1942, 1946) are a major contribution to the meat research activities. The Committee on Cooperative Meat Investigations has not been active so for several years, and to the best of my knowledge there is no particular feeling that it should be reactivated. During the past two years certain phases of meat research have been discussed at the Reciprocal Meat Conference which is sponsored by the National Live Stock and Meat Board. This Conference may be one means of securing closer cooperation in meat research between the various institutions. The value of a central clearing house to assist in correlation of the research work at various stations in order to avoid unnecessary duplication and to utilize the facilities and personnel at each station to the best advantage needs consideration. Those of you who are in states in the Tennessee Valley watershed area know that such a program is now underway on meat curing problems. In this particular case the Tennessee Valley Authority has assumed certain responsibilities in coordination of efforts. In 1944 the Conference on Cooperative Meat Investigations made certain new recommendations and revised old ones on a program for meat research. These recommendations on specific problems and on the need for cooperative effort between various departments and institutions should receive serious consideration.

In discussing the matter of techniques, I would like to mention a very

interesting report which, in essence, is as follows:—"Two types of work should be developed in the way of standard procedures for expressing differences in meat quality.

1. Simple tests which are of a routine nature and which can be carried out in the laboratory or in the commercial plant.
2. Studies of a more complicated nature on the fundamental principles which will substantiate the use of routine tests which define the differences obtained."

These remarks are from a report of the Sub-Committee on Physiological, Anatomical, Histological, Chemical and Physical Study of Meat of the Cooperative Project on a Study of the Factors which Influence the Quality and Palatability of Meat and were made nearly 25 years ago. It is rather surprising to note how applicable these statements are at present.

Any discussion of techniques applicable to meat research must proceed largely along physical, chemical, histological, and bacteriological lines. While the dairy chemist and dairy bacteriologist and their research laboratories are readily recognized as essential components of Dairy or Dairy Manufacturing Departments this is hardly true of Animal Husbandry Departments. With the exception of the Bureau of Animal Industry work in these fields is usually done in departments outside of Animal Husbandry with the result that little pressure is developed for improved techniques. Arrangements are usually made for graduate students to work in these outside laboratories to acquire needed training, experience and guidance. Once the work has been completed little opportunity exists for continuation of such a relationship. This system acts efficiently to deprive the meats section of necessary equipment, facilities and personnel and is basic to the general lack of meat research activities and especially improved techniques. If the meats man has no responsibility for techniques he may soon be out of touch with this important phase of the work. It is not advisable that the meats section function simply in a service capacity to other sections. It is hardly possible to overemphasize this point.

Of interest are six papers with discussions presented at the Reciprocal Meat Conference this past June.

1. *Methods Used in the Study of the Histological Structure of Meat.* Pauline Paul, Michigan State College.
2. *Observations on Chemical Methods Used in Meat Research.* D. E. Brady, University of Missouri.
3. *Methods Used in Studying Bacteriogenic Problems in Curing and Canning Meat.* Omar Nelson, University of Illinois.
4. *Organoleptic Tests Developed for Measuring the Palatability of Meat.* Belle Lowe, Iowa State College.

5. *Determining the Tenderness of Meat by the Use of the Warner-Bratzler Method.* L. J. Bratzler, Michigan State College.
6. *Standard Method of Cutting Pork Carcasses for Determining the Yield and Percentage of Wholesale Cuts.* R. L. Hiner, U.S.D.A.

These titles indicate the general nature of fields of meat research and the papers cover the matter of techniques with respect to each of these fields.

As has been indicated, meat research may proceed along many varied lines. It is, therefore, unlikely that any one particular type of statistical design will prove to be equally adaptable to all meats work. Care should be taken that the design used does not bias or in some way interfere with the drawing of valid conclusions. Unless one is familiar with design and analysis the help of a statistician trained in this field is indispensable. It is assumed, however, that the researcher should have a knowledge of the basic principles involved in design in order that he may intelligently plan his experiment and draw valid conclusions. Additional statistical training is valuable since it often rests with the ingenuity of the researcher to use designs which are particularly adaptable to the experiment, and the success of the researcher may therefore depend to no small extent upon his familiarity with their adaptability.

Statistics has its value as a convenient and accurate method of description and especially as a means for testing the significance of results from experimentally imposed conditions. This may be further extended to noting whether the results observed are in agreement with some already proposed hypothesis or with the conclusions that one may wish to draw. We may, therefore, test a hypothesis in the form of regression lines. For example, does the lowering of storage temperature increase the length of the induction period in a simple arithmetic or in a geometrical manner?

It is implied that the first requirement for well planned experiments is that we, in the results, provide not only a comparison of all the different treatments but also a means for testing the significance of differences between the treatments. It is therefore necessary that the treatments be replicated to serve as a standard to compare differences between treatments.

It is in the sampling procedure that one is often confronted with serious problems. Marked variation of no regular pattern is the rule rather than the exception. This uncontrolled variation may well obscure real differences between treatments unless sufficient replicates are available. In this connection it might be well to point out that with certain chemical analyses it is possible to secure increased economy as well as accuracy by increasing the number of replicates somewhat and at the same time making but a single chemical observation on each replicate instead of in triplicate.

Physiology

L. E. CASIDA
University of Wisconsin

I WOULD like to place foremost among the physiological problems in animal production those which have to do with the developmental physiology of economic characters. The field is relatively undeveloped; consequently it has the appeal of the unexplored to the investigator. Further, an understanding of the developmental physiology of characters stands a very good chance of contributing directly to the more efficient production of better livestock.

It is recognized that the term, developmental physiology, is an unorthodox one; but, having saddled myself with it, perhaps I will at least be permitted to define it as I see fit. The developmental physiology of an economic character implies defining and delimiting the steps in the process of its development. It is the breaking down of the character into its subcharacters—those which came into existence at an earlier stage. It is the resolution of a character into its antecedent or intermediary characters, or the resolution of a character complex into its components.

I would like to use an illustration from the field of reproductive physiology. (Undoubtedly there are parallels in the other fields of physiology—growth, nutrition, lactation etc., that might as well be given.) Let us consider the character, litter size in swine. This can be resolved into ovulation rate, fertilization rate and prenatal death rate, and these three antecedent characters actually control all the variation in the final character, litter size. Each antecedent in turn may admit of being broken down. For example, it can be seen that fertilization rate depends on the potential fertility of the eggs and the number of potentially fertile sperm which reach the fertilization site. It can further be seen that each of these has also antecedent characters in its development.

An examination of the association or independence (i.e., the degree of association) between the antecedent characters and the final character is next appropriate. The degree to which variation in ovulation rate, fertilization rate and prenatal death rate, *each*, govern variation in litter size under ordinary conditions should be determined.

The existing environment and population should be examined for recognizable variable factors. The effect of these variables upon each antecedent character and upon the degree to which each antecedent determines the final character should be measured. Then comes the experimental check of field observations. Environmental factors may then be varied experimentally under controlled conditions and the full range of their effects more

adequately explored. Let us assume we have made the observation (in the general population and under ordinary conditions) that prepuberal growth rate and feed intake affect ovulation rate. Let us then vary the feed intake and the growth rate experimentally and see how it affects the age at puberty; how it affects the ovulation rate at puberty; how it affects the rate at which maximal ovulation rate is attained, and also the maximal magnitude of the ovulation rate.

I think it can be seen that out of such studies, there is a possibility of finding optimal feeding and management conditions for each antecedent character and that these conditions may be brought together into a sort of a synthetic environment that will make for a maximal expression of the final economic character. The net effect of this should be a contribution to husbandry.

Knowing the environmental factors that affect a character should make it possible to discount or to control environmental effects and in many cases to increase the heritability of the character. The study of developmental physiology has a possibility of contributing to animal breeding also in cases where a final character is of low heritability, but an antecedent or intermediary character is of high heritability. We have a direct challenge to determine experimentally whether selection in such a way as to utilize the antecedent character will make for faster improvement than selection on the basis of the final character only.

The study of the effects of genetics and of feeding and management upon physiological processes can in turn lead to greater knowledge of the process itself. We may illustrate with the problem of whether low potential fertility of the ova is associated with high embryonic death rates, i.e., whether those defects of the ova which prevent fertilization grade off insensibly into or exist in common with defects which cause the death of the embryo. The development of inbred lines of animals with ova of different degrees of fertility would make it possible to study the association between fertilization rate and the embryonic death rate as we go from one strain to another. Further, finding ways to feed or manage or treat animals experimentally so that egg fertilizability is impaired would make it possible again to study the association between the fertilization potential and the rate of embryonic death.

Historically those concerned with breeding and feeding have wished to place the emphasis on the final character rather than the intermediate. This leaves the physiologist in the position of having to do the work himself of evaluating environmental and hereditary influences upon variation in sub or antecedent characters or of actively stimulating the cooperation of the geneticist and the nutritionists. At any rate it is believed that the debt

will be repaid to physiology because of the tools which may come from these other fields for prying apart the various physiological processes. Thus it is that physiological studies to throw more light on the problems of animal production may in turn reflect light upon the nature and course of physiological processes.

Finally, one last reference which has to do with experimental design in physiological studies. We commonly use a factorial design embodying from one to four factors. The main comment which I wish to make has to do with the preliminary experiments rather than the final experiment. There is a tendency to minimize the importance of preliminary experiments. It is my belief that most creative research is done in them. It is often catch-as-catch-can; it is where you are probing for a lead and a plan of attack. Each part of the plan must be tried out in a preliminary way to such an extent that a guess can be made as to its course and outcome before an elaborately designed more critical experiment is justified. Nothing is more discouraging than to plan and carry out an elaborate and time-consuming experiment and then have it fail because of inadequate preliminary study. The experiment of elaborate design is the place where the idea is performance-tested and not where the idea is conceived and gestated.

Animal Breeding[1]

L. N. HAZEL
Iowa State College

RESEARCH in genetics has shown that quantitative characters are nearly always influenced by many pairs of genes as well as by many environmental factors. Emphasis in animal breeding has accordingly shifted from Mendelian analysis toward population genetics (Fisher, 1918 and 1930; Wright, 1921 and 1931; Lush, 1945). The rate of improvement expected from applying a definite method of selection and a definite mating system to a population is mathematically predictable if certain biological, economic and genetic values are known (Dickerson and Hazel, 1944). One of the important and difficult tasks in animal breeding research is that of obtaining accurate estimates of these values and combining them properly to develop effective breeding plans for the various classes of farm livestock.

Problems of Measuring Merit

The first step in an effective breeding program is to obtain yardsticks or measures of merit which are easily applied and which reflect accurately the economic differences between animals. Ways of measuring merit more

[1] Journal Paper No. J-1810 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1127.

easily and more accurately should be a constant and fruitful field for research in animal breeding. Developments in chemistry, physics, physiology, and the application of new mechanical devices present challenging opportunities in this field.

As advances in some fields make competing products more abundant and cheaper than livestock products, emphasis may need to be shifted from one character to another. For example, milk protein is a valuable addition to the human diet. Perhaps the quality and quantity of protein in milk will receive more emphasis in dairy cattle breeding, and fat less, particularly if the trend toward increased use of vegetable fats at the expense of butterfat continues. The development of a rapid and accurate "Babcock test" for milk protein would be required before general application became practicable.

Another example of changing economic values and the necessity for continued research upon measures of merit is afforded by the long-time trend toward a lower price for lard, as compared with lean pork cuts. Competition from vegetable fats apparently has reduced permanently the price of lard until it is not economically feasible to produce more than the minimum amount necessary for the health of the animal and to make the lean cuts attractive. A method is needed for measuring the degree of fatness on live hogs so those most satisfactory in this respect can be used for breeding. In our experience, thickness of backfat can be measured on live hogs with little difficulty by inserting a narrow metal ruler through an incision in the skin over the back and pressing the ruler down to the *longissimus dorsi*. The correlation between live-hog and carcass measurements of backfat thickness was 0.83 in two trials with 48 animals. Other methods involving the use of X-rays, specific gravity or fat-soluble dyes might provide an even more accurate measurement of degree of fatness without harming the animals for breeding purposes.

Problems of Economic Value

Several different characteristics usually need to be improved simultaneously because the practical value of farm animals is influenced by several traits. Hence the second step in an effective breeding program is a definite goal or index which gives proper weight to each of the characteristics in which improvement is desired. An important factor in deciding upon the proper weight a trait should receive is the increase in net income expected to result from each unit of improvement in that trait. This increase in net income, hereafter termed the relative economic value, has received little attention in animal breeding investigations. Research should yield worthwhile and perhaps surprising results in this field where general impressions have long been the rule.

Relative economic values for fleece weight and for weaning weight of lambs are given in table 1 as an example of how such values may be found. Fewer lambs than fleeces will usually be marketed because about 22 ewe lambs must be kept as replacements for each 100 ewes of breeding age. Hence one unit of improvement in average weaning weight will increase net income of the entire enterprise less than one unit of improvement in average fleece weight relative to the net values of the two traits. That is why the relative economic values are 7.5:1 with a lamb crop of 70 percent and are 3.7:1 with a lamb crop of 120 percent. It seems probable that the prices shown in table 1 should be a little higher for weaning weight and lower for fleece weight in a farm sheep breeding program than in a range program. It is also probable that the increased cost of each additional pound of weaning weight would be higher for the farm program since additional feed otherwise marketable usually would be required to produce each additional pound of lamb on the farm, whereas much of the weaning weight in range lambs is produced in the season of the year when feed is in excess and is practically costless if the size of the flock is limited by the scantiness of the feed supply at other seasons.

Undoubtedly numerous problems not now apparent will arise when concerted efforts are made to determine exact economic values for the important traits of each class of livestock. Perhaps costs and prices vary so widely for different geographical regions and for different kinds of enterprises that widely applicable standards cannot be adopted. But attacking the problems will make clear the difficulties involved and will lead to agreement in some cases. It can hardly do any harm and is almost sure to reduce by at least a little the existing confusion and imbalance of emphasis. Certainly, determining the economic values for most characters will require more data and will be more complex than is apparent from the simple example given above.

Hereditary Variation

The individual effects of the many genes which influence quantitative characters are usually small and are in many cases easily confused with the effects of intangible environmental factors. Mendelian analysis of the genes in even a single herd or flock appears quite impossible or at least not worth the tremendous effort that would be required. On the other hand, the analysis of variation according to its general causes is a practicable goal and with proper precautions much useful information can be obtained from records currently available.

Lush (1949) has discussed recently the methods of estimating the different kinds of variation. The fraction of the observed variance in a quantitative character caused by the average effects of the genes is termed the heritability

(in the narrow sense) of the character in question. Methods of estimating heritability depend in one way or another upon measuring how closely relatives resemble each other as compared with unrelated animals. Three important questions need to be considered in designing an experiment and in analyzing the data to obtain unbiased estimates of heritability. First, what is the genetic relationship between the various kinds of relatives examined? Second, are treatment and environmental circumstances sufficiently randomized so that relatives and non-relatives have equal opportunities to be exposed to the existing treatments and environments? Third, what effects will dominance and epistasis have upon the resemblance between the relatives?

TABLE 1. RELATIVE ECONOMIC VALUES OF WEANING WEIGHT AND FLEECE WEIGHT

	Weaning weight	Fleece weight	Ratio 1:
Longtime average price per pound (or forecast of future price)	.125	.444	
Increased cost of each additional pound	.013	.040	
Net value of each additional pound	.112	.404	
Economic values assuming			
70% lamb crop	.054	.404	7.5
100% lamb crop	.087	.404	4.6
120% lamb crop	.110	.404	3.7

Estimates of heritability for staple length in Rambouillet lambs as given by Hazel and Terrill (1945) are shown in table 2. The analysis was made on an intra-year basis to eliminate yearly differences because those were largely environmental. The half-sib estimates were adjusted for extra relationship of parents and for the inbreeding of the sires because each sire was from a different inbred line. Even slight departures from random mating have a marked effect in increasing the resemblance between half-sibs.

The regressions of offspring on dam, being on an intra-sire basis, excluded average differences between the sets of ewes mated to different rams. Non-random mating systems have a relatively minor effect upon intra-sire regressions but a small adjustment was made here also to allow for whatever the mating systems had probably done to reduce differences within the sets of dams. Although there is considerable variation in the estimates in different years, the sampling errors individually are large enough to account for this. There is good agreement between the average estimates by the half-sib and intra-sire regression methods, these being .41 and .39 respectively.

Experimental designs for measuring the dominance and epistatic variance require some special features. Hazel and Lamoreux (1947) analyzed data on White Leghorns where each male was mated to several hens and each hen to several males (table 3). Such a design permits comparing the male x female interaction variance, which would be large if nicking or dominance were highly important, with the variance within families. This design

TABLE 2. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR STAPLE LENGTH (HAZEL AND TERRILL, 1945)

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred	1949	0.30	0.09	0.41	0.20
Lines	1942	.49	.12	.37	.12
Top-crosses	1941	.64	.22	.25	.18
	1942	.49	.21	.50	.15
Average		.41	.07	.39	.08

TABLE 3. ESTIMATES OF HERITABILITY, MATERNAL EFFECTS, AND NICKING IN A WHITE LEGHORN FLOCK (HAZEL AND LAMOREUX, 1947)

Kind of variance	Sexual maturity	Body weight at 22 wks.
Heritability	.27	.32
Maternal Effects	0.0	.05
Nicking	.01	.01
Unanalyzed	.72	.62

does not provide an accurate estimate of the total variance caused by dominance and epistasis unless the males and females are highly inbred.

Robinson, Comstock and Harvey (1949) used biparental crosses within each of three F_2 populations, made by crossing three inbred lines, to estimate heritability and the degree of dominance for several characters in corn (table 4). Except for husk extension, the characters with highest heritability tend to have the lowest degree of dominance and *vice versa*, as is to some slight extent automatic.

Lush (1949) pointed out the usefulness of inbred lines and identical twins in studying the magnitude and nature of hereditary variation. Ma-

terial of this sort now being developed at animal breeding laboratories should yield valuable information about many of the important characters in farm animals. In the meantime, studies of available data on noninbred material should be continued for the useful information they contain and to obtain standards against which to check the results of more complex designs. The task of cataloguing with a reasonable degree of completeness and accuracy the genetic parameters of farm animals is one of the important problems of animal breeding research. Once it is well along the road to completion much of the guesswork will have been removed from the choice of breeding plans.

TABLE 4. ESTIMATES OF HERITABILITY AND OF THE DEGREE OF DOMINANCE FOR SEVERAL CHARACTERS IN CORN (ROBINSON COMSTOCK AND HARVEY, 1949)

Character	Heritability estimated from		Degree of dominance
	Offspring-dam regressions	Offspring-sire regressions	
Plant Height	.43± .04	.60± .07	0.34
Ear Height	.41± .05	.47± .08	0.0
Husk Extension	.72± .08	.62± .10	0.96
Husk Score	.48± .07	.45± .09	0.79
Ear Number	.16± .03	.24± .05	0.54
Ear Length	.16± .04	.13± .06	0.69
Ear Diameter	.23± .04	.14± .06	1.21
Yield	.10± .04	.16± .06	1.64

Genetic Correlations

Many genes in laboratory animals, at first thought to have only one major effect, have on closer study been found to influence several apparently distinct characters. Most of the genes which cause differences in the productive characters of farm animals exert their effects through the transformation and use of food energy. Genes which enhance the expression of one such character will tend automatically to reduce the expression of another, particularly where the food supply is limited. Production of meat, milk and wool depends upon the harmonious interaction of numerous organs and tissues of the animal body. Extreme development in one direction may very likely bring about correlated responses in entirely different directions.

Correlations resulting from the action of the same genes or sets of genes on two or more different characters are termed genetic correlations. They can be estimated from records of relatives by correlating trait "x" of one relative with trait "y" of another (Hazel, 1943; Hazel, Baker, and Rein-

miller, 1943). Since large amounts of data are required to obtain accurate estimates, the actual genetic correlations in the various classes and breeds of livestock have not been studied extensively. Identical and fraternal twins in dairy and beef cattle appear to be excellent experimental material for this purpose.

Selection Indexes

Since the practical value of an animal usually depends upon several characters, an index for adding merits and demerits in the several characters provides a useful method of selection. An accurate index should evaluate each animal according to its genotype or breeding value for each of the several characters, combining them according to the relative economic value of each character. Thus the overall breeding value of an animal is defined as

$$H = a_1G_1 + a_2G_2 + \ldots + a_nG_n,$$

where the a_i represent the relative economic values discussed previously. The G_i represent the sum of the average effects of the genes for the ith character for each animal.

The G_1 cannot be known exactly because of environmental factors, epistasis and dominance. Maximum improvement from selection can be made using as the criterion of selection the index,

$$I = b_1X_1 + b_2X_2 + \ldots + b_nX_n,$$

where the X_1 represent production records or phenotypes for the several important characters. The b_i are constants chosen to make $\sum(H-I)^2$ as small as possible in the group of animals under consideration. Obtaining estimates of the b_i requires the solution of a set of simultaneous equations based on the phenotypic and genetic variances and covariances (Hazel, 1943).

Selection indexes have wider application than has generally been realized. Each trait which contributes to the economic return can be included in H regardless of whether it can be measured on all animals (e.g., sex limited characters such as butterfat or milk production in dairy cattle, litter size in hogs, carcass value in meat animals, etc.). The X_i in the index can include the performance of an animal's ancestors, collateral relatives, and progeny, as well as the animal's own records. Some of the X_i may be characters which have no economic value in themselves ($a = 0$) but which serve as useful indicators of the breeding values for other characters.

The Choice of Breeding Plans

Mass selection is an effective method of making continuous genetic improvement where heritability is high. Various aids to mass selection such

as pedigrees, family records, and progeny tests are useful in improving slightly hereditary characters which can be changed only slowly by mass selection alone. Dickerson and Hazel (1944) presented methods of calculating the amount of genetic improvement expected when various amounts of emphasis are placed upon mass selection, pedigree performance and progeny testing.

More reliance should be placed upon family formation and linebreeding with emphasis upon selection between families when epistasis is important (Lush, 1949).

If overdominance is important, as when the heterozygote is preferred over either homozygote, emphasis is shifted toward making genetically distinct strains which can be crossed for the production of market animals. The plan followed by corn breeders has been that of making inbred lines and expanding for commercial production those which cross best. Hull (1944) has suggested recurrent selection wherein members of a heterozygous strain are crossed to a tester. Then those which produce the superior crossbred progeny are used to perpetuate the strain. Comstock, Robinson and Harvey (1949) have endorsed this principle with the modification that two heterozygous strains be used. Members of each strain would be mated with the other strain, the performance of the crossbred progeny serving as the criterion on which to select those to be used as parents in perpetuating each strain. In this way each strain would steadily be changed to fit the other better and better in crosses, somewhat as keys and locks are made to fit each other. These methods of recurrent selection have a disadvantage common to other types of progeny testing; they lengthen the generation interval. If the additional accuracy gained by the test is not relatively greater than the additional time required, the rate of improvement per unit of time may actually be less than that attainable from a less elaborate method.

Literature Cited

Comstock, R. E., H. F. Robinson and P. H. Harvey. 1949. A Breeding Procedure Designed to Make Maximum Use of Both General and Specific Combining Ability. Agron. Jour. 41: 360.

Dickerson, G. E. and L. N. Hazel. 1944. Effectiveness of Selection on Progeny Performance as a Supplement to Earlier Culling in Livestock. Jour. Ag. Res. 69: 459.

Fisher, R. A. 1918. The Correlation between Relatives on the Supposition of Mendelian Inheritance. Trans. Roy. Soc., Edinburgh, 52 pt. 2: 399–433. 1918.

Fisher, R. A. 1930. The Genetical Theory of Natural Selection. Oxford Univ. Press. London.

Hazel, L. N. 1943. The Genetic Basis for Constructing Selection Indexes. Genetics 28: 476.

Hazel, L. N., Marvel L. Baker and C. F. Reinmiller. 1943. Genetic and Environmental Correlations between the Growth Rates of Pigs at Different Ages. JOURNAL OF ANIMAL SCIENCE 2: 118.

Hazel, L. N. and W. F. Lamoreux. 1947. Heritability, Maternal Effect and Nicking in Relation to Sexual Maturity and Body Weight in White Leghorns. Poultry Sci. 26: 508.

Hazel, L. N. and C. E. Terrill. 1945. Heritability of Weaning Weight and Staple Length in Range Rambouillet lambs. JOURNAL OF ANIMAL SCIENCE 4: 347.
Hull, F. H. 1944. Maize Genetics Coop. News Letter 18: 11.
Lush, Jay L. 1945. Animal Breeding Plans, 3rd ed. Iowa State College Press, Ames, Iowa.
Lush, Jay L. 1949. Heritability of Quantitative Characters in Farm Animals. Hereditas Suppl. Vol., 1949: 356–375.
Robinson, H. F., R. E. Comstock and P. H. Harvey. 1949. Estimates of Heritability and the Degree of Dominance in Corn. Agron. Jour. 41: 353.
Wright, Sewall. 1921. Systems of Mating. Genetics 6: 111.
Wright, Sewall. 1931. Evolution in Mendelian Populations. Genetics 16: 97.

THE B-VITAMINS IN RELATION TO A COBALT DEFICIENCY IN SHEEP[1]

W. H. Hale, A. L. Pope, P. H. Phillips, and G. Bohstedt[2,3]
University of Wisconsin[4]

Filmer (1933) reported that 40 gm. of dried liver fed daily would cure a malady of unknown cause affecting sheep in Australia. Working on the hypothesis that the action of the liver might be due to some mineral present, he fed an equivalent amount of liver ash and found that it was ineffective in causing a cure. Later when the ailment had been shown to be a cobalt deficiency, Filmer and Underwood (1937) found that a daily dose of the liver supplied only 20 γ of cobalt which is far below the daily requirements of a sheep. They suggested that the cobalt was converted into some organic combination in the rumen and that this compound was essential for the sheep. They also believed that this factor was stored in the liver which is true would account for the long period required to produce a cobalt deficiency in sheep.

These workers did not take into consideration that liver is an excellent source of the B-vitamins. Many of the symptoms of a cobalt deficiency in sheep are similar to symptoms of a B-vitamin deficiency observed in other animals. To check this possibility Ray *et al.* (1948) injected cobalt-deficient sheep with various members of the vitamin-B complex. Only thiamin injections appeared to be beneficial. A complete B-vitamin supplement given orally for a period of 2 weeks failed to alleviate any of the symptoms of a cobalt deficiency.

Rickes *et al.* (1948) isolated a factor (vitamin B_{12}) that contained cobalt from liver. One of the striking properties of this vitamin was its marked effect on hemoglobin formation in pernicious anemia cases in man. A cobalt deficiency in sheep is also characterized by a severe anemia. Hale *et al.* (1950) have shown that vitamin B_{12} concentrations are limited or nil in the rumen of cobalt-deficient sheep. It appeared that perhaps a cobalt deficiency in sheep might actually be a vitamin B_{12} deficiency due to failure of rumen synthesis.

The purpose of the study reported herein was to determine if vitamin

[1] Published with the approval of the Director of the Wisconsin Agricultural Experimenta Station. This work supported in part by the Wisconsin Alumni Research Foundation.

[2] We are indebted to Merck and Co., Inc., Rahway, N. J., for crystalline vitamins and the vitamin B_{12} concentrate, and to Dr. B. L. Hutchings of the Lederle Laboratories Div., American Cyanamid Co., Pearl River, N. Y., for synthetic folic acid.

[3] The crystalline vitamin B_{12} was generously supplied by Merck and Co., Inc., through the courtesy of Dr. D. F. Green.

[4] Department of Animal Husbandry and Biochemistry, Madison, Wisconsin.

B_{12} when injected or fed orally would alleviate any of the symptoms of a cobalt deficiency in sheep. Various combinations of the B-vitamins were also given orally to cobalt-deficient sheep for an extended period of time.

Vitamin B_{12} Supplementation

Experimental and Results

West (1948) had reported hematological responses with single injections of 3, 6, and 150 γ of vitamin B_{12} in human cases of pernicious anemia. When this experiment was undertaken there were no reports in the literature as to the effect of vitamin B_{12} therapy on cobalt-deficient sheep. For this study 4 lambs with the general symptoms of a cobalt deficiency as

TABLE 1. EFFECT OF INJECTED CRYSTALLINE VITAMIN B_{12} ON HEMOGLOBIN LEVELS OF COBALT-DEFICIENT LAMBS
Hb. gm. %

Lamb. no.	Days after injection			
	0	4	8	14
87[1]	8.26	8.21	9.06	8.91
94[1]	8.91	9.80	9.22	9.96
89[2]	3.97	4.08	4.20	Removed
90[3]	4.20	3.44	3.10	2.74

[1] 40γ B_{12} per animal 4 injections.
[2] 30γ B_{12} per animal 3 injections.
[3] 25γ B_{12} single injection.

described by Russell (1944) were injected with crystalline vitamin B_{12} in amounts from 25 to 40 γ. All injections were subcutaneous. Hemoglobin was determined according to the method of Evelyn (1936). The effect of the vitamin on the hemoglobin level of these lambs is shown in table 1.

Lambs Nos. 87 and 94 do not represent a severe cobalt deficiency, however, the initial hemoglobin values were below accepted values. These 2 animals each received 4 doses (10 γ each) of vitamin B_{12} on alternate days. If the vitamin exerted a similar effect in cobalt-deficient sheep as in human cases of pernicious anemia a marked rise in hemoglobin would be expected by the 14th day. Lambs Nos. 90 and 89 which represent a severe cobalt deficiency were given 3 injections of 10 γ each and one injection of 25 γ respectively. No remission of any of the symptoms was seen in the 4 lambs as measured by hemoglobin levels or increased appetite.

Due to the limited amount of vitamin B_{12} available the dosages used were very small. This is well demonstrated by the fact that rumen ingesta of cobalt-supplemented sheep may contain 50–60 γ of vitamin B_{12} per 100 gm.

dry matter. Injections of the vitamin probably should approximate the amount found in the rumen of sheep receiving a normal level of cobalt. When the vitamin became more plentiful a cobalt-deficient lamb (No. 83) was injected with 100 γ daily for a period of 4 weeks. The effect of the injections on the hemoglobin of this lamb is shown in table 2. A slight increase in the hemoglobin of this lamb occurred but it was not a sharp rise. The final value was still below normal. During this 4-week period the appetite of the lamb remained poor and there was a weight gain of only 5 lb.

In connection with the vitamin B_{12} injection experiments, another one to test a crude vitamin B_{12} concentrate fed orally to 4 cobalt-deficient

TABLE 2. HEMOGLOBIN LEVELS OF 2 COBALT-DEFICIENT LAMBS RECEIVING LARGE DAILY DOSES OF VITAMIN B_{12} FOR A PERIOD OF 4 WEEKS

Labm no.	Method of administration	Daily dose	Hb. gm. %			
			0 week	1 week	2 weeks	4 weeks
83	Injected	100 γ	6.57	6.62	7.80	8.09
95	Oral	200 γ	6.62	7.24	7.55	8.63

lambs was undertaken. The results obtained were encouraging but on subsequent analysis it was found that the concentrate contained a much higher level of cobalt that could be accounted for by the vitamin B_{12} present. Since the results of that experiment cannot be satisfactorily evaluated they have been discarded. Later, sufficient vitamin B_{12} became available to administer large doses to a single lamb. The vitamin was thoroughly mixed with finely powdered NaCl and 200 γ were given to the lamb daily by capsule. The effect of this oral administration on the hemoglobin of this lamb is also shown in table 2 (lamb No. 95). Although there was a rise of 2 gm.-percent in the hemoglobin of this lamb there was a gain of only 3 lb. during the 4-week experimental period. The appetite of the lamb remained poor throughout the period.

The results of the above trials indicated that vitamin B_{12} was of little or no value (either injected or oral) in alleviating the symptoms of a cobalt deficiency in lambs. This is in agreement with the finding of Becker *et al.* (1948). The small size of the dosages used in the first part of this study and by Becker *et al.* (1948) left much to be desired. That question has been partially answered by the use of large daily doses of the vitamin for an extended period with 2 cobalt-deficient lambs. There was a small increase in the hemoglobin of the 2 lambs receiving massive doses of vitamin B_{12}

but the rate of increase was far below that which is seen following cobalt supplementation. Although vitamin B_{12} is synthesized in large amounts in the rumen, it appears that it is not an important dietary constituent in alleviating a cobalt deficiency. This indicates that the marked effect exerted by cobalt upon ruminants is probably by some route other than through vitamin B_{12}.

Other B-vitamin Supplementation

Experimental

While investigating a cobalt deficiency in sheep, 1 cobalt-deficient lamb was given a complete B-vitamin supplement (less vitamin B_{12}) daily for a

TABLE 3. DAILY AMOUNTS OF B-VITAMINS GIVEN ORALLY TO COBALT-DEFICIENT SHEEP

B-vitamins	Lot 1	Lot 2	Lot 3	Lot 4
	mg.	mg.	mg.	mg.
Thiamin	—	—	1.8	1.8
Riboflavin	—	—	3.6	3.6
Niacin	—	—	30.6	30.6
Calcium pantothenate	—	—	12.2	12.2
Pyridoxine	—	2.4	—	2.4
Folic acid	—	0.3	—	0.3
PABA	—	—	61.3	61.3
Choline	—	—	500.0	500.0
Biotin	—	—	0.12	0.12
Vitamin K	—	—	0.3	0.3

period of 5 weeks. The appetite of this lamb returned to normal followed by a weight increase and a slow rise in hemoglobin. Although Ray *et al.* (1948) had reported that a B-vitamin supplement over a 2-week period was of no value in treating a cobalt deficiency, the results obtained from the 1 lamb mentioned above was encouraging enough for a study of this type to be continued in a preliminary way. Eight cobalt-deficient lambs were divided into 4 lots and given the combination of B-vitamins orally by capsule as shown in table 3. One lot was to serve as the control and received no B-vitamin supplement of any type. The second received only pyridoxine and folic acid. Pyridoxine was included in this group because Ray *et al.* (1947) found it to be low in the blood of cobalt-deficient sheep. The role of folic acid in reticulocyte formation is well known. The third lot which served as a check group for group No. 2 received the complete B-vitamin supplement less pyridoxine and folic acid. The fourth lot received the complete vitamin mixture given to lots 2 and 3.

The vitamin K was present in the vitamin mixture which was on hand at the start of the study and to avoid complicating the problem, it was included in later mixtures. This vitamin mixture has been used successfully with chicks fed a synthetic ration. The amount given the lambs was ½ the recommended level for chickens. The vitamin supplements were given daily for a period of 7 weeks from September 20 until November 12.

Results

While it was appreciated that satisfactory statistical analysis could not be made with such few animals, the following data do give a tentative basis for planning future studies.

TABLE 4. EFFECT OF ORAL B-VITAMIN SUPPLEMENTATION ON HEMOGLOBIN OF COBALT-DEFICIENT LAMBS

Hb. gm. %

Lot no.	Treatment	Lamb no.	Sept. 20	Sept. 30	Oct. 10	Oct. 24	Nov. 7
1	None	90	5.95	5.21	5.07	6.76	6.76
		94	7.00	5.71	4.20[1]	—	—
		Av.	6.48	5.46	4.64	—	—
2	Folic acid $+B_6$	85	8.63	7.00	8.40	4.64	5.07
		96	4.86	6.50	5.80	5.60	5.95
		Av.	6.74	6.75	7.10	5.12	5.51
3	Complete B-vitamins less folic $+B_6$	86	8.91	8.09	9.13	8.09	8.26
		82	5.80	8.48	9.22	10.24	9.80
		Av.	7.36	8.28	9.18	9.16	9.03
4	Complete B-vitamin supplement	80	5.65	6.27	5.38	7.87	9.80
		97	—	5.54	9.47	10.43	10.73
		Av.	—	5.90	7.42	9.15	10.26

[1] Died Oct. 22, 1949.

The effect of the oral B-vitamin supplement on hemoglobin levels is shown in table 4 and on growth in table 5. One of the lambs in the non-supplemented lot died 1 month after the start of the experiment. The other lamb failed to gain weight and its hemoglobin remained low.

The 2 lambs which received folic acid and pyridoxine had a decrease in average hemoglobin and a marked weight loss occurred with 1 lamb. The general well-being of the lambs in this lot as well as their appetite was very poor. There was an extremely distorted ratio of the neutrophiles and lym-

phocytes in these 2 lambs. The neutrophiles as a percentage of the total white cells present were 71 and 79, and of the lymphocytes 20 and 14 as compared to a normal sheep with values of 23–33% for neutrophiles and 53–67% for lymphocytes (Gardner, 1948). From these limited observations it appeared as if the folic acid and pyridoxine supplements aggravated the cobalt deficiency.

The results obtained with the third lot which received the complete B-

TABLE 5. EFFECT OF ORAL B-VITAMIN SUPPLEMENTATION ON GROWTH OF COBALT-DEFICIENT LAMBS

Lot no.	Treatment	Lamb no.	Sept. 12	Oct. 13	Oct. 20	Nov. 7
			lb.	lb.	lb.	lb.
1	None	90	69	69	72	69
		94	56	54	52[1]	—
		Av.	62.5	61.5	62.0	—
2	Folic acid $+B_6$	85	69	66	66	70
		96	80	80	77	71
		Av.	74.5	73.0	71.5	70.5
3	Complete B-vitamins less folic $+B_6$	86	85	84	82	73
		82	107	102	108	116
		Av.	96.0	93.0	95.0	94.5
4	Complete B-vitamin supplement	80	67	70	79	86
		97	90	92	95	101
		Av.	78.5	81.0	87.0	93.5

[1] Died Oct. 22, 1949.

vitamin supplement less folic acid and pyridoxine are difficult to interpret. Lamb No. 86 had a poor appetite which was not improved by the supplement. A weight loss occurred but was not accompanied by a reduction in hemoglobin. Shortly after the termination of this study the lamb died. The other lamb (No. 82) of this group gave an entirely different response. This lamb was losing weight steadily at the time the vitamin supplements were started. Within a few days after the start of the supplement the appetite of the lamb improved and a weight increase followed. There was a rise of 4 gm. percent in the hemoglobin of this lamb during the 7-week period.

The 2 lambs which received the complete B-vitamin supplement showed a marked response. Appetite improved greatly and both lambs gained steadily during the entire period. The hemoglobin of both lambs increased and ap-

proached normal levels near the end of the supplementation period. The lambs appeared normal in all respects. When the supplementation was stopped the general symptoms of a cobalt deficiency reappeared. Gall *et al.* (1949) have shown that there is a reduction of the numbers and types of microorganisms in the rumen of cobalt-deficient sheep. Perhaps the organisms that fail to grow due to a lack of cobalt are concerned with B-vitamin synthesis.

Summary

Vitamin B_{12} injected into cobalt-deficient lambs in doses of 100 γ daily (1 lamb) or given orally in 200 γ daily doses (1 lamb) for a period of 4 weeks failed to produce a satisfactory response.

A complete B-vitamin supplement given daily by mouth for a period of 7 weeks reversed all symptoms of a cobalt deficiency (2 lambs). A supplement of only folic acid and pyridoxine aggravated a cobalt deficiency as measured by external appearances, hemoglobin values, weight losses, and a highly distorted lymphocyte and neutrophile ratio (2 lambs). A complete B-vitamin supplement less folic acid and pyridoxine in 2 other lambs gave varying results.

These data suggest that the physiological role of cobalt in sheep is by some route other than through vitamin B_{12} even though there is an extremely large synthesis of this vitamin in the rumen of cobalt-supplemented sheep. The beneficial action of cobalt may be through production of the members of the B-vitamins in the rumen.

Literature Cited

Becker, D. E., S. E. Smith and J. K. Loosli. 1949. Vitamin B_{12} and Cobalt Deficiency in Sheep. Science 110: 71.

Evelyn, K. A. 1936. A Stabilized Photoelectric Colorimeter with Light Filters. Jour. Biol. Chem. 115: 63.

Filmer, J. F. 1933. Enzootic Marasmus of Cattle and Sheep. Preliminary Report Having Special Reference to Iron and Liver Therapy. Austral. Vet. Jour. 9: 163.

Filmer, J. F. and E. J. Underwood. 1937. Enzootic Marasmus. Austral. Vet. Jour. 13: 57.

Gall, L. S., S. E. Smith, D. E. Becker, C. N. Stark and J. K. Loosli. 1949. Rumen Bacteria in Cobalt Deficient Sheep. Science 109: 468.

Gardner, M. V. 1947. The Blood Picture of Normal Laboratory Animals. Notes from the Biochem. Res. Foundation.

Hale, W. H., A. L. Pope, P. H. Phillips and G. Bohstedt. 1950. The Effect of Cobalt Upon Vitamin B_{12} Synthesis in the Rumen of Sheep. Journal of Animal Science. In press.

Ray, S. N., W. C. Weir, A. L. Pope, G. Bohstedt and P. H. Phillips. 1948. Studies on the Role of Cobalt in Sheep Nutrition. Journal of Animal Science 7: 3.

Ray, S. N., W. C. Weir, A. L. Pope and P. H. Phillips. 1947. Studies on the Concentration of Some B-vitamins in the Blood of Normal and Cobalt Deficient Sheep. Jour. Nutr. 34: 595.

Rickes, E. L., N. G. Brink and F. R. Koniuszy. 1948. Crystalline Vitamin B_{12}. Science 107: 396.

Russell, F. C. 1944. Minerals in Pastures, Deficiencies and Excesses in Relation to Animal Health. Tech. Com. No. 15, Imp. Bur. Nutr.

West, R. 1948. Activity of Vitamin B_{12} in Addisonian Pernicious Anemia. Science 107: 398.

ALFALFA AND ALFALFA-BROME GRASS HAYS FOR GROWING AND FATTENING LAMBS[1]

T. B. KEITH,[2] RUSSELL H. STARK,[3] AND C. W. HICKMAN[2]

Idaho Agricultural Experiment Station and U. S. Department of Agriculture

THE comparative nutritive values of alfalfa hay and alfalfa-brome mixtures is a subject much discussed in areas where erosion control must be considered. It is an established fact that alfalfa-grass mixtures reduce the erosion of soil to a much greater extent than a crop of straight alfalfa. The relative nutritive value of a hay made from "straight" alfalfa and a hay made from a mixture of alfalfa and brome grass has not been clearly established. It is known, however, that the stage of maturity and the prevailing weather at the time of harvesting contribute considerably to the quality of hay produced from either straight alfalfa or alfalfa-grass mixtures. Certain livestock producers have indicated a preference for straight alfalfa while others have reported excellent results with alfalfa-grass mixtures. This may reflect differences in harvesting and handling methods rather than the potential nutritive values of the two types of hay.

A summary of work conducted at the South Dakota State Experiment Station (1946–47) (Jordan 1949) shows alfalfa to be superior to an alfalfa-brome grass mixture for wintering ewes insofar as gains in ewe weight are concerned. The average fleece weights and average lamb weights were the same for both groups of ewes.

Studies made on dairy cows at the Wyoming Agricultural Experiment Station (1947–48) show the average daily milk yield of cows on a combination of alfalfa and native hay was 33.2 pounds as compared to 32.9 pounds for alfalfa alone. The gains of yearling heifers were 1.13 pounds daily when fed alfalfa hay alone as compared with 1.17 pounds daily on a combination of alfalfa and native hay.

Phillips and Loughlin (1949) of the New Hampshire Agriculture Experiment Station have reported on the "Composition and Digestible Energy of Hays Fed to Cattle." One sample of brome grass and seven samples of alfalfa were reported. The calories of digestible energy for the seven samples of alfalfa ranged from 2,466 to 2,809 as compared to 2,949 calories for the single sample of brome grass. The percentage of digestible energy of the single sample of brome grass was 67.6 as compared to a range of 54.5 to 61.2 for the seven samples of alfalfa. The percentage of total protein for the brome grass

[1] Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No, 313.

[2] Animal Husbandry Department, Idaho Agricultural Experiment Station.

[3] Aberdeen Nursery Unit, Soil Conservation Service, U. S. Department of Agriculture.

was 12.15 as compared to a range of 13.78 to 22.00 for the alfalfa. The lignin percentage was considerably lower for the brome grass sample, being 7.58 as compared to a range of 8.97 to 12.01 for the alfalfa samples. The crude fiber content was not significantly different for the brome grass, being 31.1 percent compared to a range of 26.1 to 40.5 percent for the alfalfa samples. A summary of the review of literature indicates that brome grass is definitely lower in protein but not significantly different in the percent of utilizable total energy.

Experimental Procedure

Hay Production

In order to obtain lots of hay that had been produced and harvested uniformly, arrangements were made to grow straight alfalfa hay and definite percentages of alfalfa-brome mixtures under irrigation at the Aberdeen Branch Station. For the mixtures, alfalfa was seeded in alternate rows spaced 6″ apart with smooth brome grass (*Bromus inermis*). During the growing period the alfalfa and brome grass became intermingled similar to a natural mixture. Pure alfalfa was seeded on a nearby strip.

Previous to harvesting the hay, part of the grass was cut and removed from half the alfalfa-brome mixture. This was done to obtain two lots of mixed hay that would contain different percentages of grass. Alfalfa and brome grass require about the same length of time to mature for hay production in this environment. The hays were cut at the one-tenth bloom stage, field cured with favorable weather conditions.

This resulted in the production of hays containing the following dry weight percentages: (1) 100 percent alfalfa; (2) 76 percent alfalfa and 24 percent brome grass; and (3) 67 percent alfalfa with 33 percent brome grass.

These hays were baled with a pick-up baler and transported with a truck to the Agricultural Experiment Station at Moscow, Idaho to be fed to lambs for the study of the comparative feeding value. All three hays were graded as U. S. No. 1.

Experimental Animals

Thirty Suffolk ewe lambs were selected from the University flock for the feeding test. Their ages ranged from 141 to 155 days. The initial weights of the individual lambs ranged from 62 to 89 pounds. Previous to the initiation of the feeding test, these lambs had been permitted to nurse and graze with their mothers on a white blossom sweet clover pasture. The lambs were divided into 3 lots. The lambs in each lot were fed equal parts of the concentrate mixture and hay for a period of 77 days between August 5 and October 21, 1948. The concentrate mixture is shown in table 1. Lot 1 was

fed straight alfalfa hay, lot 2 was fed hay containing 24 percent brome grass and the hay for lot 3 contained 33 percent brome grass. All lambs were fed in individual stalls three times daily. Each lamb was permitted to consume as much total feed as desired. During the intervals between feedings, all lambs had access to sheltered pens and outside lots free of vegetation. Water and salt were available at all times to all lots.

TABLE 1. CONCENTRATE MIXTURE

Feed	Parts per 100
Oats, whole	40
Barley, rolled	29
Bran	20
Peas, whole	10
Sodium chloride	1

Results

The average daily gains shown in table 2 were $.36 \pm .06$, $.34 \pm .05$ and and. $36 \pm .06$ pounds, respectively, for the lambs in lots 1, 2 and 3. The coefficient of variability of individual gains for lot 1 was 17 percent, lot 2, 15 percent, and lot 3, 17 percent.

The average feed required for each 100 pounds of gain was 889 ± 141, for the lot fed straight alfalfa, 945 ± 127 for the lot fed the 24 percent mixture, and 922 ± 118 for the lot fed the 33 percent mixture. The differences are not significant.

TABLE 2. SUMMARY OF THE DATA RELATING TO AVERAGE GAINS AND FEED REQUIREMENTS OF THE THREE GROUPS FOR A PERIOD OF 77 DAYS

	Lot Hay mixture	Number of individuals	Average initial weight	Average daily gain	Average daily ration	Feed for each 100 pounds of gain (av.)
		Pounds	Pounds	Pounds	Pounds	Pounds
1	Alfalfa	10	79	.36	3.2	889
2	Alfalfa 76 parts, Brome Grass 24 parts	10	80	.34	3.2	945
3	Alfalfa 67 parts, Brome Grass 33 parts	9*	79	.36	3.3	922

* One lamb was removed due to sickness.

Summary

A ration composed of equal parts concentrate and hay was used to study the comparative value of alfalfa hay alone and alfalfa-brome hay mixtures

for growing and fattening lambs. Two alfalfa-brome mixtures were used. One contained 24 percent grass and the other 33 percent grass by dry weight. The gains and feed required to make 100 pounds of gain were practically the same for the lambs fed the different hays. The small differences in gains and feed requirements were not due to the differences in the nutritive value of the hays.

Literature Cited

———1947–48. No Advantage to Native Hay. Fifty-Eight Annual Report of the Wyoming Agriculture Experiment Station, pp. 27.

———1946–47. Alfalfa, Brome and Alfalfa-Brome fro Wintering Breeding Ewes. Annual Station Report, South Dakota State College of Agriculture and Mechanical Arts, pp. 23.

Jordan, R. M. 1949. Mixed Hays—a Means of Cutting Feed Costs. Sheep and Goat Raiser 29: 18.

Phillips, T. C. and M. E. Loughlin, 1949. Composition and Digestible Energy of Hays Fed to Cattle. Jour. Agr. Res. 78: 389.

THE FEEDING VALUE OF NORGHUM SORGHUM WHEN FED TO LAMBS[1]

R. M. JORDAN[2]

South Dakota Agriculture Experiment Station

HERETOFORE the Northern Great Plains area has had no variety of sorghum that could be relied upon to stand the cold spring weather and mature before frost. Sorghums developed in the Southern Plains region of the United States do not fit the requirements of the northern plains. In spite of those shortcomings, sorghums are planted because of its drought resistant qualities and high feed value. However, Norghum sorghum is well adapted to conditions in the Northern Great Plains and offers none of the disadvantages mentioned for the sorghum grains that are adapted to growing conditions in the Southern Plains States.

Jones and Dickson (1928) reported comparable results with grain sorghums and with corn when fed to lambs. Cox (1947) reported satisfactory gain in comparison to corn and that it was unnecessary to grind sorghums when fed to lambs.

Since Norghum, a new variety of grain sorghum developed at the South Dakota Experiment Station, was of unknown feeding value, two lamb feeding trials and one digestion trial were conducted by the South Dakota Experimental Station during 1949–50.

Experimental Procedure

Fifty lambs were used in each of the two feeding trials and were weighed individually and randomized into their respective lots on the basis of their weight. The lambs were hand-fed grain and hay twice a day and received as much feed as they would eat. This amounted to about $1\frac{3}{4}$ pounds of grain and $1\frac{1}{4}$ pounds of hay daily. In both trials one lot received a full feed of unground Norghum sorghum grain, brome hay, and 10 percent, by weight, of the grain ration of soybean oil meal. The other lot received the same ration except No. 2 shelled yellow corn was substituted for the whole sorghum grain. Flake salt, flake salt and bonemeal mixed 50–50, and fresh water were provided the lambs at all times.

To determine the digestibility of Norghum grain, four lambs were fed 850 grams of Norghum sorghum grain per head daily. The preliminary and collection period were both ten days duration and during this 20 day period the lambs ate all the feed fed with no weigh-back resulting. No hay was

[1] Contribution from the Animal Husbandry Department. Approved for publication by the Director of the Agriculture Experiment Station as contribution No. 244 of Journal Series.

[2] Assistant Animal Husbandman, South Dakota State College Experiment Station.

fed during the trial. Watson *et al.* (1949) reported no significant difference in digestibility of grain when fed with or without roughage.

TABLE 1. CHEMICAL ANALYSIS OF NORGHUM SORGHUM AND CORN

	Total dry matter	Total protein	Ether extract	Crude fiber	N-free extract	Minerals
Norghum*	90.00	12.03	2.76	1.77	71.96	1.48
No. 2 Corn*	90.00	9.93	4.12	2.32	72.25	1.37

* Corrected to 90 percent dry matter basis. The Norghum sorghum as harvested contain 91 percent dry matter.

The above table shows the relationship between Norghum sorghum and No. 2 Dent corn, and is based on an average of five different samples of grain from Norghum sorghum. This analysis indicates that Norghum compares favorably with corn in all constituents.

The chemical analysis of Norghum sorghum grain which was fed in these trials and No. 2 corn are given in table 1.

TABLE 2. COMPARISON OF NORGHUM SORGHUM AND SHELLED CORN AS A FEED FOR FATTENING LAMBS

Comparison	Norghum sorghum, soybean oil meal, brome hay		Shelled corn, soybean oil meal, brome hay	
	Expt. I	Expt. II	Expt. I	Expt. II
Lambs per lot	25	25	25	25
Death Loss	0	1*	0	2
Days on feed	75	119	75	119
Av. initial weight, lbs.	70.7	56.4	70.5	67.3
Final weight per lamb, lbs.	95.5	96.9	95.0	100.2
Average daily gain. lbs.	.33	.34	.33	.36
Average daily ration, lbs.				
Norghum sorghum	1.72	2.03		
Shelled yellow corn			1.64	1.90
Soybean oil meal	.17	.20	.16	.19
Brome hay	1.18	1.34	1.19	1.37
Feed per 100 pounds gain, lbs.				
Norghum sorghum	513	601		
Shelled yellow corn			495	526
Soybean oil meal	51.3	60	49.5	52.6
Brome Hay	351	398	358	380
Carcass grade				
Choice	20	21	20	21
Good	5	3	5	2

* Lamb removed from experiment due to prolapsed rectum.

Results and Discussion

Feeding Trials

The results of the two feeding trials are summarized in table 2. In both trials the lambs fed whole sorghum were easier to keep on feed and actually ate more grain per head than the corn-fed lambs. In spite of this additional feed intake their daily gains did not on the average exceed the corn-fed lambs. The corn-fed lambs gained on the average in the two trials .35 pound per head daily as compared to .34 pound per head daily for the Norghum fed lambs; the difference was not significant. The feed required per hundred pounds of gain was in favor of the corn-fed lambs in both trials. In these trials on the basis of feed required per hundred pounds of gain, Norghum has 90 percent the value of shelled corn since it required about 60 pounds more total feed per hundred pounds of gain. This may be due to the fact that considerable grain passed through the lambs unmasticated.

There was no significant difference in the carcass grade of the lambs fed Norghum sorghum compared to that of the corn fed lambs.

The average coefficient of apparent digestibility of Norghum sorghum as compared to corn are given in table 3.

TABLE 3. COEFFICIENT OF APPARENT DIGESTIBILITY OF NORGHUM SORGHUM WHEN FED TO LAMBS WITHOUT ROUGHAGE

Item	Dry matter	Crude protein	Ether extract	Crude fiber	N free extract
Lamb No. 1	88.35	74.98	83.07	51.92	93.34
Lamb No. 2	85.20	71.40	78.97	29.42	91.16
Lamb No. 3	86.18	70.20	75.13	37.91	91.86
Lamb No. 4	88.51	81.12	84.32	38.12	92.28
Average	87.06	74.42	80.37	39.10	92.16
Well dried dent corn[1]		76	91	57	94

[1] Average of 22 trials as listed in Feeds and Feeding by Morrison.

The average coefficients of apparent digestibility are considerably higher than those obtained by Smith (1948). However, his work was conducted with cattle which would have slightly lower coefficients of digestibility of grains as cited by Watson *et al.* (1948).

The average coefficient of digestibility of corn as given by Morrison (1947) exceeds the digestibility of the Norghum sorghum. The greatest difference is in ether extract and crude fiber. It was apparent during the digestion trial that considerable grain passed through the lambs unmasticated and this may be the main reason for the lower digestibility of the Norghum sorghum as compared to corn.

Summary

Two feeding trials and one digestion trial with lambs were conducted to determine the value of Norghum sorghum as compared with corn. From these trials the following conclusions were drawn:

1. The new variety of sorghum named Norghum is a palatable feed for lambs when fed whole.

2. Lambs fed Norghum sorghum made about as good gains as corn-fed lambs.

3. The corn-fed lambs required less feed per hundred pounds of gain than the Norghum-fed lambs.

4. Norghum sorghum compares favorably with No. 2 dent corn in all nutrients and contains about two percent more total protein.

5. The coefficient of apparent digestibility of all of the feed nutrients is lower for Norghum sorghum than for corn.

Literature Cited

Cox, Rufus F. 1947. Grain Comparison for Fattening Lambs, Circular 1-S-47, Kansas Agricultural Experiment Station.

Jones, J. M. and P. E. Dickson. 1928. Grain Sorghums Versus Corn for Fattening Lambs. Texas Agr. Expt. St. Bul. 379.

Morrison, F. B. 1947. Feeds and Feeding, 20th Edition, Morrison Publishing Company.

Smith, Ed. F. 1948. Effect of Grinding on the Nutritive Value of Grain Sorghums for Fattening Steer Calves. Mimeograph report Kansas Livestock Feeders' Day.

Watson, C. J., J. W. Kennedy, W. M. Davidson, C. H. Robinson and G. W. Muir. 1949. Relative Associative Effects of the Roughages, Timothy, and Alfalfa with Barley. Sci. Agr. 27: 175.

THE USE OF PROGESTERONE IN THE SYNCHRONIZATION OF THE ESTRUAL PERIODS IN A GROUP OF EWES AND THE EFFECT ON THEIR SUBSEQUENT LAMBING RECORDS[1]

C. C. O'Mary, A. L. Pope, L. E. Casida
University of Wisconsin

MAKEPEACE, Weinstein and Friedman (1937) reported that progesterone inhibits ovulation after mating in the rabbit. This inhibition does not extend more than 48 hours after the last injection of the hormone. Everett (1948) found the 4-day cycle in rats to be retarded one day by injection of 1.5 mg. of progesterone on the first day of diestrus, and that repeated daily injections continued to retard ovulation. However, injection of progesterone on the first day and third day of diestrus, omitting treatment on the second day, accelerated the expected ovulation about 24 hours. When estrogen levels are elevated progesterone facilitates ovulation, at least in the rat (Everett, 1948), and rabbit (Sawyer, *et al.*, 1950). Rothchild and Fraps (1949) demonstrated the ovulation-inhibiting effect of progesterone in the chicken. These workers emphasize the relation between timing and effect in that progesterone can be either ovulation-inhibiting or ovulation-inducing depending on the interval elapsing from injection to ovulation.

Dutt and Casida (1948) were able to control the time of onset of estrus in a group of ewes by injections of progesterone. A dosage of 10 mg. was more effective in inhibiting heat than a dosage of 5 mg. When the progesterone treatment ceased the animals which were begun on experiment at three different stages of the estrual cycle all showed estrus at essentially the same time. Also fertilized eggs were recovered from ewes treated at the different stages of the cycle on both dosages.

The purpose of the present work was to synchronize, by use of progesterone, the estrual periods in a group of ewes within which many stages of the estrual cycle were represented at random. The subsequent effect on fertility was studied by comparing the lambing percentage of progesterone treated ewes with that of control ewes.

Synchronization of the estrual periods in a group of animals would be desirable in connection with superovulation, artificial insemination and embryo transplantation.

[1] Paper from the Department of Genetics and the Department of Animal Husbandry (Genetics No. 430).

Plan of the Experiment

A mixed flock of grade and purebred ewes was acquired at the beginning of the 1949 breeding season. Each animal was permitted to go through at least one estrual period prior to the beginning of treatment. The occurrence of estrus was determined by use of vasectomized rams which were kept freshly painted on the underline and brisket. A ewe was considered as coming into estrus when she was first observed with a newly painted rump. Although rams were allowed to run continually with the flock, observations of appearance of estrus (painted rump) were made only twice daily. This method of determining estrus was continued until all animals were bred.

The thirty-nine ewes in this experiment were divided at random into two groups of 19 and 20 animals, designated as control and treated groups respectively. Treatment consisted of 14 daily subcutaneous injections of 10 mg. of progesterone in 2 cc. of corn oil. The total dosage per ewe was 140 mg. of progesterone.

All ewes were placed on experiment Oct. 8, the day on which the first animal was observed to come into heat. Treatment was started on the day after all animals had shown at least one estrual period. Plans were made to breed the treated animals at approximately the mid-point of the breeding period of the control group. This plan was made on the assumption that all treated ewes would be in heat on the third day after the end of treatment which was the approximate time found by Dutt and Casida (1948) in ewes receiving a 10 mg. dosage of progesterone daily.

All animals had shown one estrual period by Oct. 25, thus furnishing a base date for each animal from which to predict the next occurrence of estrus and to determine the stage in the cycle of the treated ewes at the beginning of the treatment. Thus the observation period ended on the treated group on Oct. 26 and the treatment period began. This period continued until Nov. 8, when the breeding period began. The observational period for the control group, however, extended from Oct. 8 to Nov. 1, when their breeding period began. The breeding period ended for both groups on Nov. 18. These dates will be used as reference points in discussion of the results.

Results and Discussion

A total of 20 percent of the treated ewes came into heat during their treatment period as contrasted with 89.5 percent of the control ewes during the same period (table 1).

The maximum percent of the control animals coming into heat in any one day was 21 and this occurred only one time during the entire 42 day

period. This maximum is shown in the observational period in comparison with a 15% maximum for those to be treated. The maximum percent coming into heat on any one day during the treatment period was 10.0 for the treated group and for the same interval of time 10.5 for the control group.

The maximum in the treated group occurred on the eighth day of treatment (two animals) and represented half of all the treated animals coming into heat during this period. The lengths of estrual cycles for these particular animals were 19 and 20 days. Apparently the dosage was not high enough

TABLE 1. EXPERIMENTAL SYNCHRONIZATION OF ESTRUAL PERIODS IN EWES BY INJECTION OF PROGESTERONE

		Percent of animals coming into heat				
		Oct. 8–25	Oct. 26–Nov. 8		Nov. 9–18	
Group	Number of Animals	Maximum in any one day	Maximum in any one day	Total for period	Maximum in any one day	Total for period
Control	19	21	10.5	89.5	10.5	52.6
			Treatment period			
Treated	20	15	10.0	20.0	70.0	100.0

to suppress heat completely in these animals and their performance was similar to that of some animals observed by Dutt and Casida (1948) in a group of ewes on a lower dosage. The remaining 10 percent coming into heat during treatment were ewes that were in the 15th day of their cycles at the time treatment was started. The progesterone may not have had time to inhibit the onset of estrus or a higher dosage may be required at that stage of the cycle as the animal's own production of progesterone is presumed low due to regression of her corpora lutea. Dutt and Casida (1948) found that the 5 mg. dosage was not as effective in inhibiting estrus in ewes in the 12 day stage as those in the 4 day stage. Thus it appears that a higher dosage is required to prevent estrus when begun in later stages of the cycle.

All of the treated animals came into heat and were bred during their breeding period with 70 percent coming in heat on the third day after the end of treatment. During this same period, November 9–18, only 52.6 percent of the controls came into heat; the other 47.4 percent had been in heat during the last 8 days of the treatment period for the treated animals, thus giving a total of 100 percent of the controls in heat and bred during their breeding period.

Five rams were used to breed the ewes and each ram was bred to nearly equal number of ewes in each group. Ewes from each group conceived to each of the rams.

TABLE 2. THE EFFECT OF PROGESTERONE ON THE BREEDING AND LAMBING PERIODS AND ON FERTILITY AS MEASURED BY THE PERCENTAGE OF EWES LAMBING

Group	Number of animals bred	Percent of animals in group	Duration of breeding interval		
			Total range (days)	Mean (days)	Standard deviation (days)
Control	19	100	18	9.2	5.1
Treated	20	100	8	3.7	1.7
Group	**Number of animals lambing to 1st service**	**Percent of animals in group**	**Duration of lambing interval**		
			Total range (days)	Mean (days)	Standard deviation (days)
Control	15	78.9	19	9.7	5.7
Treated	16	80.0	7	3.9	1.9

All of the control animals were bred within 18 days (table 2). The average time at which they were bred was 9.2 days after the beginning of their breeding period, and nearly half of the control group had been bred by the end of Nov. 9. The standard deviation was 5.1 days. Treatment reduced the range within which the animals were bred to 8 days. The mean was 3.7 days after the end of treatment and the standard deviation was 1.7 days. In this case 85% of the animals were bred Nov. 10–12 inclusive.

The time required for lambing was also reduced from 19 days in the control group to 7 days for the treated. The mean times at which the ewes lambed were 9.7 days and 3.9 days after the first lamb was born in each of the respective groups. Although the time of estrus was not controlled completely, the variation in the breeding time was shortened which in turn shortened the lambing period.

Progesterone had no apparent effect on the fertility of the ewes since 78.9 percent of the control and 80.0 percent of the treated ewes lambed. The number of lambs born was 20 in the control group and 19 in the treated group.

Summary

The effects of 10 mg. progesterone daily for 14 days on synchronization

of estrual periods of ewes during the breeding season and on subsequent lambing percentage was studied in a controlled experiment involving thirty-nine ewes. Seventy percent of the injected ewes came into heat on the third day after the end of treatment and the average time at which they were bred was 3.7 days after end of treatment, standard deviation 1.7 days. In the control group the average time of breeding was 9.2 days from the beginning of their breeding period, standard deviation 5.1 days.

The standard deviation of the lambing period was reduced in the progesterone treated group to 1.9 days as compared to 5.7 days in the control group.

No difference in the fertility of the two groups was demonstrated since the percentage of ewes lambing was 78.9 of the control group and 80.0 of the treated group, and the number of lambs born was 20 in the former group and 19 in the latter.

Literature Cited

Dutt, R. H. and L. E. Casida. 1948. Alteration of the Estrual Cycle in Sheep by Use of Progesterone and its Effect Upon Subsequent Ovulation and Fertility. Endocr. 43: 208.

Everett, John W. 1948. Progesterone and Estrogen in the Experimental Control of Ovulation Time and Other Features of the Estrous Cycle in the Rat. Endocr. 43: 389.

Makepeace, A. W., George Louis Weinstein and Maurice H. Friedman. 1937. The Effect of Progestin and Progesterone on Ovulation in the Rabbit. Amer. Jour. Physiol. 119: 512.

Rothchild, Irving and R. M. Fraps. 1949. The Induction of Ovulating Hormone Release from the Pituitary of the Domestic Hen by Means of Progesterone. Endocr. 44: 141.

Sawyer, C. H., J. W. Everett and J. E. Marke. 1950. "Spontaneous" Ovulation in the Rabbit Following Combined Estrogen-Progesterone Treatment. Proc. Soc. Exp. Biol. Med. 74: 185.

THE MAGNITUDE OF CERTAIN SOURCES OF VARIABILITY IN DIGESTIBILITY DATA[1]

BURCH H. SCHNEIDER[2] AND HENRY L. LUCAS[3]
West Virginia University and University of North Carolina

IN a previous publication, Schneider *et al.* (1950) show that it is warranted to use average digestibility data when assessing the nutritive value of individual samples of feed. The use of such data leads to a substantially more precise assessment of nutritive value than does the failure to consider digestibility at all, or than does the practice of distinguishing between feeds only as members of major feed classes.

The additional precision just noted occurs despite the variation in digestibility observed between samples of the same feed. This does not mean that the within-feed variation is unimportant. The digestibility of any particular sample may deviate considerably from the tabled average value and thus, even though the use of average data is worth while, there still may remain substantial errors in the assessment of nutritive value. This study deals with the magnitudes and sources of these errors.

Data and Procedure

The same data were used as in the study referred to above. They were selected from the compilation by Schneider (1947), using the criteria described in the previous publication. They involved 194 feeding stuffs studied by 94 authors who investigated 2,402 samples of feed. This entailed 4,629 individual digestion trials.

The data were divided into five feed classes: hays, dry roughages other than hays, green soiling crops, silages, and concentrates. They were then subdivided according to the species of animal involved, i.e., cattle, sheep, swine, and horses, and according to whether digestibility was determined "by difference" or on feeds fed alone.

Analyses of variance were conducted on each of these subclasses. This was done separately for total digestible nutrients, and for the digestion coefficients of organic matter, crude protein, crude fiber, nitrogen-free extract, and ether extract.

The variability to be expected in digestibility data is attributable to numerous factors. It was feasible, however, to consider only the four following variance sources:

[1] Supported in part by a grant from Swift & Company. Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 417.

[2] West Virginia University.
[3] Institute of Statistics, University of North Carolina (Raleigh Campus).

(1) Between feeds
(2) Between authors within feeds
(3) Between samples within authors
(4) Between trials (one collection period on one animal) within samples

The components of variance to indicate the amounts of variability from the four sources were estimated by the method of Ganguli (1943).

The between-feed components of variance were given attention in the previous study (Schneider *et al.*, 1950). Since, however, they are not parts of the errors when using average digestibility data, the other three components (i.e. the between-author, between-sample and between-trial components) were investigated in the present study.

Certain summarizing analyses were conducted in order to ascertain whether or not feed class, species of animal, and method of determining digestibility (alone or "by-difference") materially affect the sizes of the components. These were weighted least squares analyses, using the logarithms of the estimated components. The weights were the degrees of freedom for the corresponding mean squares. Negative estimates of components rarely occurred, but where they did, the data were coded so that all values were greater than 1.0 before taking logarithms. The overall average values of the three components for the digestion coefficients and for the total digestible nutrients were also computed. Because logarithms were employed in the summarizing analyses, all averages to be presented are weighted geometric means. From a practical standpoint, these probably give a truer picture than the corresponding arithmetic means because the effect of occasional very high estimates is minimized.

Certain additional analyses were undertaken because digestion coefficients may be affected by chemical composition. The analyses of variance previously noted were extended to covariance analyses with the proximate nutrient contents of the feeds (omitting ash) as the independent variables. The components of variance were then re-estimated from the adjusted sums of squares. An approximate method was used, because to obtain unbiased estimates of the components after covariance would have involved a very large amount of computation. These results will not be presented in any detail, but are nevertheless important.

Results

The first results to be presented are the overall average values for the three error components before covariance adjustment for proximate composition. These components indicate the relative amounts of variability arising from the different sources. These, along with their totals and the corresponding standard deviations (square roots of the totals), are shown in

table 1. The components are presented both as their actual values and as percentages of the total variances.

Under the assumption that tabulated digestibility averages are not subject to errors, the standard deviations in table 1 estimate the error which will be exceeded approximately one-third of the time when applying average digestibility figures to individual samples fed to single animals. Actually, since the tabulated averages are subject to errors, the application errors

TABLE 1. OVER-ALL AVERAGE ESTIMATED COMPONENTS OF VARIANCE FOR THE SEVERAL DIGESTION COEFFICIENTS AND FOR TOTAL DIGESTIBLE NUTRIENTS—ACTUAL VALUES AND AS PERCENT OF TOTAL VARIANCE (THE LATTER IN PARENTHESES)

Component estimated	Organic matter	Crude protein	Crude fiber	N-free extract	Ether extract	Total digestible nutrients
Between-author	20(50)	48(36)	38(29)	32(33)	234(32)	33(60)
Between-sample	12(30)	64(48)	62(47)	51(53)	393(55)	15(27)
Between-trial	8(20)	22(16)	32(24)	14(14)	97(13)	7(13)
Total	40	134	132	97	724	55
S.D.[1]	6.3	11.6	11.5	9.8	26.9	7.4

[1] These standard deviations are calculated on the assumption that average digestibility data are not subject to error when applying average digestibility data to particular samples of feed, fed to single animals, and are simply the square roots of the sum of the between-author, between-sample and between-trial components of variance. If, as is the actual case, however, the average figures are subject to error, the error variance for the average must be added to the above sum before taking the square root. This is best illustrated by formulae. Let

σ_a^2 = the between-author component
σ_s^2 = the between-sample component
σ_t^2 = the between-trial component
S.D. = the standard deviation.

Then, if the average is not subject to error,

$$\text{S.D.} = \sqrt{\sigma_a^2+\sigma_s^2+\sigma_t^2}.$$

The averages in digestibility tables are usually simple averages of all individual trials involved. The variance of such averages is

$$\frac{\Sigma_p^2}{n^2}\sigma_a^2+\frac{\Sigma_m^2}{n^2}\sigma_s^2+\frac{1}{n}\sigma_t^2$$

where

n = total number of trials
m = number of trials on a sample
p = number of trials by an author

The quantities, m and p, are usually quite different for the several samples and authors involved in all of the trials on a feed, but, of course, $\Sigma_p = \Sigma_m = n$.

The correct standard deviation is thus given by

$$\text{S.D.} = \sqrt{\left(1+\frac{\Sigma_p^2}{n^2}\right)\sigma_a^2+\left(1+\frac{\Sigma_m^2}{n^2}\right)\sigma_s^2+\left(1+\frac{1}{n}\right)\sigma_t^2}.$$

are somewhat larger than the data indicate. This point is noted in the footnote to table 1.

It is seen from table 1 that the largest errors occur for the digestibility of ether extract. The errors for the digestibility of crude protein and of crude fiber are comparable in magnitude and next largest in size. The errors in the digestibility of nitrogen-free extract are less than those for crude protein and crude fiber, and those for the digestibility of organic matter and for total digestible nutrients are, in general, the smallest of all. Of greatest importance from the standpoint of this paper, however, is the finding that

TABLE 2. COMPONENTS OF VARIANCE IN DIGESTION COEFFICIENTS AS AFFECTED BY FEED FOR THOSE CASES FOUND SIGNIFICANT—ACTUAL VALUES ONLY

Component estimated	Digestion coefficient	Hays	Dry roughages other than hays	Green soiling crops	Silage	Concentrates
Between-author	Crude Protein	9	468	13	96	5
Between-sample	Crude Fiber	47	13	65	26	856
Between-trial	Organic Matter	5	14	4	8	15
Between-trial	Crude Protein	12	143	10	12	23
Between-trial	Crude Fiber	5	19	14	15	745
Between-trial	Total Digestible Nutrients	4	12	3	6	19

the largest portions of error in digestibility data are those associated with authors and samples. The portion associated with trials is relatively small.

The approximate methods used for removing the effects of proximate composition indicated that the between-author and between-sample components shown in table 1 should be reduced in size by roughly one-third and at most by one-half. No change in the between-trial component would occur, of course, because there is no composition variance between trials on the same sample of feed.

The results of the analyses (not adjusted for composition) to ascertain the effects of feed class, species of animal, and method of determining digestibility are shown in tables 2, 3, and 4. Only those cases in which such effects were found to be statistically significant are presented. The actual values only are given, because expressing them as percentage of total has no clear meaning in these comparisons.

In table 2 the large magnitude of the following should be noted: the between-author components for the digestibility of crude protein in the case of silages and dry roughages other than hays the between-trial component

for the digestibility of crude protein in the case of dry roughages other than hays, and the between-sample and between-trial components for the digestibility of crude fiber in the case of concentrates. Other differences occurring although statistically significant, seem not large enough to have much practical significance.

The most noticeable results in table 3 are the large between-sample com-

TABLE 3. COMPONENTS OF VARIANCE IN DIGESTION COEFFICIENTS RELATED TO SPECIES OF ANIMAL FOR THOSE CASES FOUND SIGNIFICANT—ACTUAL VALUES

Component estimated	Digestion coefficient	Cattle	Sheep	Swine	Horses
Between-sample	Crude Fiber	84	87	8	250
Between-sample	Total Digestible Nutrients	54	48	159	35
Between-trial	Organic Matter	10	12	3	13
Between-trial	Crude Fiber	50	54	5	75

TABLE 4. COMPONENTS OF VARIANCE IN DIGESTION COEFFICIENTS AS RELATED TO METHOD OF DETERMINATION FOR THOSE CASES FOUND SIGNIFICANT—ACTUAL VALUES

Component estimated	Digestion coefficient	Feeds fed alone	Digestibility determined by difference
Between sample	Crude Fiber	27	140
Between-sample	Ether Extract	94	1642
Between-trial	Organic Matter	5	13
Between-trial	Crude Fiber	16	65
Between-trial	N-free Extract	7	32
Between-trial	Ether Extract	45	206
Between-trial	Total Digestible Nutrients	5	11

ponent for the digestibility of crude fiber in the case of horses, and the very low one for swine. Also of interest are the large between-sample component in the case of total digestible nutrients for swine, and the small between-trial component in the case of the digestibility of crude fiber for swine. The remarkable similarity of the components for cattle and for sheep should be called to attention.

In table 4, it is striking that the components for the "by-difference" method are consistently at least two and usually several times as large as those for feeds fed alone. The most marked case is for the between sample component for the digestibility of ether extract.

Investigations of how the results in tables 2, 3, and 4 would be changed by considering proximate composition were not made.

Discussion

The results obtained have an important bearing both on the collection of and on the use of digestibility data. They also have some other interesting aspects. Before discussing these matters, it is important to note the meaning of the three components of error which were studied.

The between-trial component is attributable mainly to animal variation, but chemical and minor sampling errors are also included. The between-sample component measures almost solely the inherent variation in digestibility of different samples of a given feed. This variation stems from factors such as genetic differences in plant materials, variations in soil fertility, plant environment, and methods of curing and of storage. The between-author component is attributable to differences in technique and the grosser variations of factors described for the between-sample component. It also is affected by the fact that different authors may call somewhat different feeds by the same name.

Many of the above factors associated with the between-author and between-sample components probably have their effects on digestibility indirectly, i.e., through their effect on the chemical composition of the feeds. This being the case, it is advantageous before continuing the discussion to summarize certain of the results as concisely as possible considering the composition.

Reasoning from the overall average values shown in table 1, and the effects which adjustment for proximate composition has on those values, the total error variance in digestibility data may be divided roughly as follows:

Variance associated with proximate composition	25–45%
Variance associated with authors	20–40%
Variance associated with samples	20–35%
Variance associated with trials	10–25%

In the case of both authors and samples, the above figures represent the variance remaining after the amount associated with proximate composition is removed.

It is of considerable practical importance that one of the largest portions of error in digestibility data is associated with the variation in proximate composition. If, therefore, proximate composition as well as the kind of feed, could be taken into account in assigning digestion coefficients to particular samples, a substantially increased precision in the assessment of nutritive value would be realized. The standard deviations in table 1 would be reduced by 15 to 25%. Formulae by which to adjust digestion coefficients for proximate composition are under study and will be presented in another publication.

It is also of practical importance that the between-author and between-

sample components are large. This means that the accuracy of tabulated average digestibility data is determined mainly by the number of authors who study a feed. The number of samples studied by each author is of less importance, and the number of trials conducted per sample is of minor importance. This is seen more clearly by studying the formula for the error of a mean given in the footnote to table 1.

It is apparent, then, that accurate average digestibility data cannot be obtained by any one worker, or by a few workers each doing a large number of trials on a single feed or feed sample. This will be true at least until much more is known, both qualitatively and quantitatively, concerning the factors in feeds which affect digestibility, and concerning factors involving the animals used, such as plane of feeding and physiological status. Until such time then, to obtain accurate average data will require many workers, each investigating several samples of a feed. Only two or three digestion trials per sample are needed. Workers with extensive facilities might better study a few samples of several or many feeding stuffs, rather than devote all of their facilities to a single sample of a single feeding stuff or to a few feeds at a time. It seems evident that the most efficient use of digestibility facilities would be obtained only by coordinated and cooperative studies.

Another item of practical importance is brought out by the data in table 4, namely, that the "by-difference" method of determining digestibility is subject to higher errors than the method involving feeds fed alone. Hence, the "by-difference" method should be avoided unless associative digestibility effects are suspected or the animal will not properly consume a ration consisting entirely of the feed of interest.

It seems worth while, before discussing other aspects of the results, to speculate on possible means of decreasing the errors associated with digestibility data. Since the between-trial component is the smallest of the several considered, it will not be given further attention. The between-author and between-sample components, even after adjustment for proximate composition, are certainly large enough, however, to be of much concern.

As was noted earlier, many of the factors which contribute to the between-author and between-sample components act through the effect they have on chemical composition of the feed. This was supported by the fact that a consideration of proximate composition materially reduced these components. Physical status may also be involved. It seems logical, however, that a greater amount than is accounted for by proximate composition actually is related to the chemical and physical character of the feeds. It would seem very important then to intensify the research already being carried on, in which the proximate nutrients are being divided into component parts, or which has as its purpose a basically different nutrient analysis for feeds.

The effects on digestibility of minerals, vitamins, plane of feeding, and physiological status of the animals employed should also be given attention.

In table 1 it is noted that the overall error to be expected for the different digestion coefficients is inversely related to the average content of the corresponding nutrients in feeding stuffs considered as a whole. This seems to agree with the data in table 2, in which the large between-author and between-trial components for the digestibility of crude protein in dry roughages other than hays appear to be attributable to the relatively low protein content of some of these feeds. They are also possibly due to the relatively high variability in type and amount of protein. A similar explanation might serve for the between-author component in the case of the digestibility of crude protein for silages. Further, perhaps the large between-sample and between-trial components for the digestibility of crude fiber in concentrates is due to the low content of fiber in these feeds.

Little explanation can be offered for the effects observed in table 3. Apparently horses digest the crude fiber in different samples much more variably than do the other species. The variance is large in the amount of total digestible nutrients that swine derive from different samples. Also, in the case of swine, the small components of variance for the digestibility of organic matter and crude fiber are notable.

Regarding the results in table 4, it would be expected that the between-trial components would be larger for the "by-difference" method than when feeds are fed alone. This is because the error in the "by-difference" method is the cumulated error of two trials. Also, in some experiments the amount of the feed tested is small relative to the basal ration, and the indirect computations, basing percentages on differences, give high variability. It would not be expected on this basis that the two methods would differ for the between-sample and between-author components. The large between-sample components may be caused by determining "by-difference" digestibility with different basal rations.

Summary and Conclusions

A compilation of published digestibility data was studied statistically in order to discern the relative importance of certain sources of variations.

It was found that 25 to 45 percent of the within-feed variance in digestibility is associated with variations in proximate composition. The amount associated with authors was 20 to 40 percent, that with samples of feed 20 to 35 percent, and that with trials 10 to 25 percent.

It was further found that the variability in digestibility of a given nutrient tends to be inversely related to the content of that nutrient in the feed. Especially high variances were noted for the digestibilities of ether

extract, of crude protein in certain roughages, and of crude fiber in concentrates.

The "by-difference" method of determining digestibility gave much higher values for certain components of variance than did the method in which feeds are fed alone. Certain species of animal were found to digest certain nutrients more variably than do others.

In view of the results, it is evident that average digestion coefficients should be adjusted for proximate composition in applying them to particular samples. Related to this conclusion is the suggestion that an even greater portion of the variance could be related to feed composition if nutrients other than those in proximate composition were considered, or if a different chemical scheme for characterizing feeds were developed.

It was also concluded that accurate average digestibility data can be obtained only if a feed is studied by a relatively large number of authors, each investigating several samples of that feed. Only two or three trials need be made per sample. Coordinated and cooperative studies would seem to be the best means of attaining this end.

Literature Cited

Ganguli, Mohanlal. 1943. A Note on Nested Sampling. Sankhya 5: 449.

Schneider, Burch H., 1947. Feeds of the World, Their Digestibility and Composition. Morgantown, W. Va. Agr. Expt. Sta.

Schneider, Burch H., Henry L. Lucas, Helen M. Pavelch and Mary Ann Cipolloni. 1950. The Value of Average Digestibility Data. JOURNAL OF ANIMAL SCIENCE. 9: 373.

CELLULOSE DIGESTION IN GOOD AND POOR QUALITY ROUGHAGES USING AN ARTIFICIAL RUMEN[1]

WISE BURROUGHS, H. G. HEADLEY, R. M. BETHKE AND PAUL GERLAUGH
Ohio Agricultural Experiment Station

DIGESTION experiments with cattle fed simplified rations produced results in this laboratory indicating that efficiency of roughage dry matter digestion was dependent upon the presence or absence of certain ration nutrients or feed components needed by rumen microorganisms. The nutrients or feed components which favorably influenced roughage digestion in cattle experiments were protein (N ×6.25), (Burroughs *et al.*, 1949a, 1949b and 1950a), a water extract of alfalfa hay, and the ash of good quality alfalfa hay, Burroughs *et al.* (1950b).

More recently a laboratory technique or artificial rumen, Burroughs *et al.* (1950c) was developed for purposes of studying physiology of rumen microorganisms and making critical observations upon influential factors involved in the micro-biological digestion of roughages. Preliminary usage of this technique indicated that cellulose digestion of filter paper by rumen microorganisms could be materially influenced by the addition or withdrawal of certain substances such as alfalfa ash, a complex mineral mixture, and an autoclaved water extract of either cow manure or rumen ingesta.

The purpose of this paper is to extend observations with the artificial rumen using, instead of filter paper, certain roughages commonly fed to cattle including those of both good and poor quality, respectively, and further, to present direct evidence that the efficiency with which a roughage is digested is dependent upon the presence or absence of essential nutrients in the roughage or ration which are required for maximum functioning of rumen microorganisms.

Experimental Methods

The methods employed in this study were essentially the same as those described earlier, Burroughs *et al.* (1950c). Artificial rumens were first charged with roughage and with microorganisms taken directly from the rumen before the morning feeding of a steer subsisting on an all-alfalfa hay ration. Fermentation was allowed to proceed for 36-hours at which time the laboratory apparatus was dismantled and the fermentation residue divided into two equal portions. One portion was saved for chemical analysis and bacteriological examinations. The other portion served as inoculum

[1] Published with the approval of the Director of the Ohio Agricultural Experiment Station. Supported in part by a Grant-in-Aid from Swift and Company, Chicago, Illinois.

for a second 36-hour fermentation upon a new supply of the roughage under investigation. This procedure was repeated during eight successive 36-hour fermentation periods.

Twelve artificial rumens were studied simultaneously. They consisted of two batteries of six glass fermentation flasks, 500 ml. capacity, immersed in two respective glass chambered water baths maintained at 40° C. Each flask was closed with a 3-hole rubber stopper. Two holes were fitted with tubing such that a common supply of carbon dioxide gas could be passed through each of the six flasks. The other hole was fitted with a removable

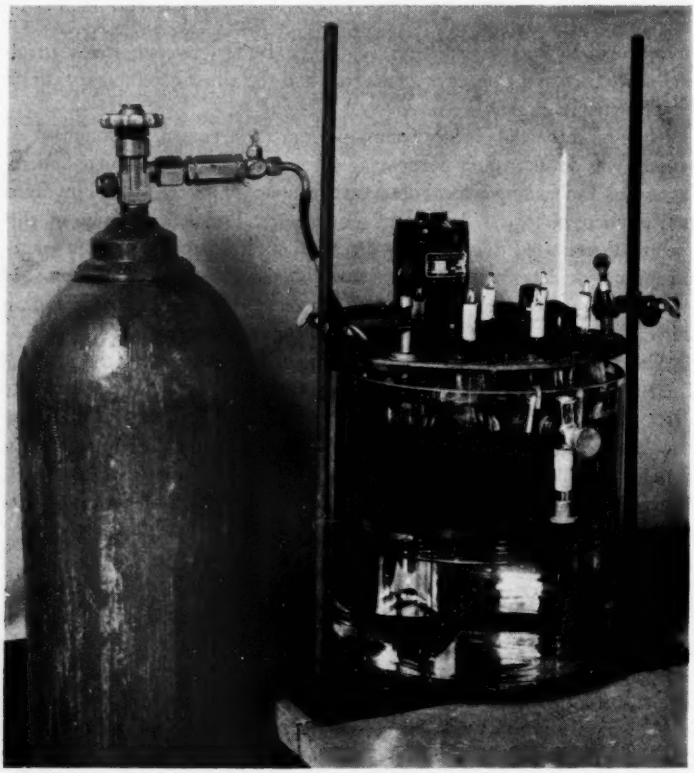

Figure 1. Equipment used in in vitro cellulose digestion with rumen microorganisms. Note the carbon dioxide tank fitted with needle valve attached to series of six 500 ml. capacity fermentation vessels emersed in a water bath maintained at 40° C.

rubber cap for hydrogen ion regulation. One of the units is shown in figure 1.

The roughages studied consisted of four good quality and four poor quality forages. The four good quality roughages were dehydrated meals consisting of two shipments of alfalfa, one of red clover, and one of rye. The poor quality roughages were corn stover, wheat straw, corncobs, and a mixture of mature timothy and blue grass hay. Each of these eight roughages are described in table 1 as analyzed for protein, moisture, ash, and cellulose.

TABLE 1. ANALYSIS OF ROUGHAGES STUDIED

Roughage	Moisture %	Protein %	Ash %	Cellulose %
Alfalfa hay (20% dehydrated meal)	8.6	20.0	8.7	12.8
Alfalfa hay (17% dehydrated meal)	5.4	16.1	10.1	26.7
Red clover hay (17% dehydrated meal)	7.4	21.6	13.0	21.6
Rye hay (17% dehydrated meal)	5.0	16.6	21.8	21.4
Corn stover	7.9	4.6	5.4	32.8
Wheat straw	7.9	1.4	5.8	47.7
Corncobs	7.2	2.1	1.4	42.8
Timothy-blue grass hay (Mature)	8.0	6.1	4.7	38.7

Three experimental flasks were used in studying each roughage. The contents of these flasks differed only with respect to the additions of supplements added to them every 36 hours. The only addition in the first flask aside from distilled water, roughage, and inoculum was an available source of nitrogen. This consisted of 0.94 gm. ammonium sulfate added initially and 0.47 gm. added each succeeding 36-hour period. This amount of ammonium sulfate was also added periodically to the second and third flasks for purposes of ruling out the known influences of adequate or inadequate protein for rumen micro-biological digestion of roughages.

The contents of the second flask were similar to the first except that 50 ml. of the following complex mineral solution was added initially and 25 ml. added each following 36-hour period:

Sodium phosphate, monbasic, gms.	52.50
Sodium bicarbonate, gms.	52.50
Potassium chloride, gms.	7.50
Sodium chloride, gms.	7.50
Magnesium sulfate, gms.	2.25
Calcium chloride, gms.	0.75
Ferrous sulfate, gms.	0.15
Manganous sulfate, gms.	0.08
Zinc sulfate, gms.	0.08
Copper sulfate, gms.	0.04
Cobalt chloride, gms.	0.02
Distilled water, ml.	2000

Similarly, the contents of the third flask were the same as flask 2 except that 150 ml. of autoclaved water extract of manure was added at the beginning of each fermentation period. Each flask had a volume of fermentation material totaling 350 ml.

The autoclaved manure extract was prepared by collecting freshly defecated manure from a steer receiving good quality alfalfa hay. Ten pounds of manure was mixed thoroughly with 15 pounds of warm tap water. The watered manure was transferred to a heavy cotton bag and the liquid portion squeezed out with the aid of a lard press. Enough hydrochloric acid was added to reduce the pH to 5.0. The acidified liquid was autoclaved at 15 lbs. for 60 minutes in unstoppered bottles. After cooling it was centrifuged slowly through a Sharples centrifuge. The liquid was then neutralized with 0.5 M. sodium carbonate and stored in the refrigerator.

The amount of roughage introduced in each flask every 36 hours was sufficient to supply an equivalent amount of cellulose as found in one gram of filter paper. The cellulose content of airdry filter paper was approximately 94 percent.

Usually one good and one poor quality roughage were studied simultaneously in which three flasks in one water bath were reserved for one forage and three flasks in the other water bath were reserved for the second forage. The other three flasks in each of the two water baths were regularly charged with one gm. of filter paper every 36-hours rather than with a natural roughage. The supplements added to these three filter paper flasks in each unit were similar to the three respective additions added to each hay or forage being studied. The supplements were: (1) available nitrogen, (2) complex minerals plus available nitrogen, and (3) autoclaved manure extract plus minerals plus nitrogen. The purpose of these filter-paper-series-repetitions was an over-all check or control in ascertaining the degree of constancy attained between experimental periods upon factors influencing microbiological digestion of cellulose which fall outside the nutritional factors being studied.

The original inoculum was obtained with the use of a large bore stomach tube inserted into the rumen of a steer approximately three years of age. The rumen contents collected was squeezed through four thicknesses of a No. 50 grade cheese cloth. The liquid portion constituted the inoculum of which 140 ml. was introduced into each fermentation flask at the beginning of an experiment. Care was taken in keeping the inoculum warm during collection. Precautions were also taken in avoiding excessive aeration, and the time interval was kept at a minimum between collection of inoculum and introduction into the artificial rumens.

The bacteriological examinations included Gram stains at the beginning

and end of each 36-hour fermentation period. Also, periodic observations were made for the presence of protozoa using a hanging-drop type of glass slide.

Results and Discussion

The results obtained in the various repetitions of the filter paper series which were carried out in conjunction with the respective roughage series were in the main rather uniform. Adding only available nitrogen to filter

TABLE 2. THE INFLUENCE OF A COMPLEX MINERAL SOLUTION AND AUTOCLAVED WATER EXTRACT OF MANURE UPON *IN VITRO* CELLULOSE DIGESTION OF FILTER PAPER BY RUMEN MICROORGANISMS

Flask description	36-hour fermentation period							
	1	2	3	4	5	6	7	8
Filter paper and available nitrogen only								
No. 9, begun 7- 2-49	86	33	1	−1	−2	1	2	−1
No. 2, begun 7-14-49	53	11	1	0	0	0	−2	0
No. 8, begun 7-14-49	40	2	3	−3	3	0	−6	−2
No. 2, begun 7-26-49	41	12	−3	−3	1	5	−2	−1
No. 8, begun 7-26-49	30	41	4	−4	1	0	0	0
No. 7, begun 8- 8-49	80	26	−2	−4	1	−3	7	−2
Average	55	21	1	−2	1	0	0	−1
Filter paper and available nitrogen plus complex minerals								
No. 8, begun 7- 2-49	88	4	0	−2	0	0	−2	1
No. 4, begun 7-14-49	84	40	29	40	46	48	28	24
No. 10, begun 7-14-49	81	58	31	44	46	47	14	9
No. 4, begun 7-26-49	76	49	17	16	17	4	2	3
No. 10, begun 7-26-49	66	80	65	53	58	46	34	11
No. 9, begun 8- 8-49	84	35	47	60	49	52	32	−2
Average	80	44	32	35	36	33	18	8
Filter paper and available nitrogen plus complex mineral plus manure extract								
No. 7, begun 7- 2-49	86	82	34	88	81	54	82	86
No. 6, begun 7-14-49	86	76	82	71	85	93	91	75
No. 12, begun 7-14-49	86	81	74	75	90	93	88	93
No. 6, begun 7-26-49	90	51	82	61	42	79	95	91
No. 12, begun 7-26-49	89	82	88	60	78	76	86	90
No. 11, begun 8- 8-49	83	84	78	80	90	63	84	46
Average	87	76	73	73	78	76	88	80

paper resulted in fairly satisfactory cellulose digestion the first 36 hours, followed by poor digestion the second 36 hours, and no digestion beyond 72 hours (table 2).

Adding the complex mineral solution to filter paper and available nitrogen greatly increased cellulose digestion throughout all eight 36-hour periods. The initial digestion was uniformly quite high as presented in table 2. During the next five periods cellulose digestion on the average was about half as high as initially observed. Beyond the sixth fermentation, filter paper digestion in the presence of complex minerals dropped somewhat further indicating that if the series had been continued very little digestion would have occurred on the average beyond the eighth 36-hour period.

The addition of autoclaved water extract of manure to filter paper in the presence of complex minerals and available nitrogen resulted in very efficient cellulose digestion initially which persisted throughout the eight 36-hour periods. As can be seen in table 2 there was only an occasional low value in this series which was almost always preceded and followed by a uniformly high digestion value.

The roughage series results are presented in table 3. In general, the pattern of cellulose digestion with each of the poor quality roughages was somewhat similar. Adding only available nitrogen to corncobs, corn stover, wheat straw, or timothy-blue grass hay resulted in poor cellulose digestion which became progressively worse toward the end of the eight fermentation periods. The addition of complex minerals along with available nitrogen greatly increased cellulose digestion with each of the poor quality roughages. This increase was maintained throughout the entire fermentation series. No further increase in cellulose digestion occurred in these roughages when manure extract was added in addition to available nitrogen and complex minerals.

The four good quality roughages differed from the four poor quality roughages in that each good quality forage was essentially unaffected by the addition of either complex minerals or manure extract. Cellulose digestion of rye hay and clover hay were uniformly high averaging about 65 per cent (table 3) irrespective of supplements added or withheld from fermentation flasks. Although the two shipments of alfalfa hay each were digested poorer (about 45 percent, see table 3) than the rye and clover hays, nevertheless the digestibility of these two good quality hays were also unaffected by the addition of minerals or manure extract.

Bacteriological observations were not made in detail, however, Gram stains and the presence of protozoa were similar to those reported earlier, Burroughs *et al.* (1950c). With good cellulose digestion occurring in the flasks, the flora appeared rather similar to the flora taken from the rumen of

TABLE 3. THE INFLUENCE OF A COMPLEX MINERAL SOLUTION AND AUTOCLAVED WATER EXTRACT OF MANURE UPON *IN VITRO* CELLULOSE DIGESTION OF POOR AND GOOD QUALITY ROUGHAGES BY RUMEN MICROORGANISMS

(Data expressed as percentage cellulose digestion)

Flask description	36-hour fermentation period								
	1	2	3	4	5	6	7	8	Aver.
Corncobs with following supplements:									
Nitrogen only	36	20	24	−14	11	3	−2	8	11
Complex minerals+N	68	65	68	67	74	70	68	69	68
Manure extract+Mnrls.+N	67	70	64	70	68	67	62	67	63
Corn stover with following supplements:									
Nitrogen only	59	52	43	30	36	24	16	0	33
Complex minerals+N	68	64	61	62	64	68	65	55	61
Manure extract+Mnrls.+N	59	55	54	55	54	54	58	51	55
Wheat straw with following supplements:									
Nitrogen only	32	20	−3	−4	26	−8	5	9	10
Complex minerals+N	40	50	43	50	46	34	42	38	43
Manure extract+Mnrls.+N	46	52	47	42	48	40	46	56	47
Timothy-blue grass mature hay with following supplements:									
Nitrogen only	55	50	44	18	20	22	23	16	31
Complex minerals+N	52	51	52	57	40	52	45	34	48
Manure extract+Mnrls.+N	53	45	53	45	45	45	43	43	47
Rye hay (immature and dehydrated) with following supplements:									
Nitrogen only	74	84	62	57	59	57	69	56	65
Complex minerals+N	73	83	61	61	61	57	56	56	64
Manure extract+Mnrls.+N	65	65	83	53	57	59	56	49	61
Clover hay (immature and dehydrated)									
Nitrogen only	72	69	62	67	70	63	64	69	67
Complex minerals+N	75	74	65	69	59	67	61	62	66
Manure extract+Mnrls.+N	68	69	67	64	68	70	62	60	66
Alfalfa hay (17% dehydrated) with following supplements:									
Nitrogen only	56	48	46	40	44	45	38	34	44
Complex minerals+N	56	47	46	44	42	42	46	37	45
Manure extract+Mnrls.+N	52	43	43	39	42	38	41	35	42
Nitrogen only	64	52	49	48	44	42	47	36	48
Complex minerals+N	58	50	47	43	49	35	50	40	47
Manure extract+Mnrls.+N	60	43	45	37	41	37	46	44	44

the steer. Poor cellulose digestion in a flask almost always resulted in flora changes, either in numbers present or their individual size, and in a few instances in the predominating types observed. Protozoa were always present in flasks showing some cellulose digestion. The smaller forms were invariably found, however, some of the larger types of protozoa would seem to disappear and reappear in a flask from fermentation period to period even though a high degree of cellulose digestion was occurring each period.

Discussion

The results presented in this paper furnish additional support to the general concept that rumen microorganisms have nutritional requirements which must be fulfilled if they are to digest roughage (cellulose) efficiently in their symbiotic role with cattle and other ruminants and further, that these nutrients are found in ample quantities in certain good quality roughages and are present in inadequate amounts in certain poor quality roughages. The types of nutrients required by rumen microorganisms cannot be specifically listed at this time but there is evidence suggesting that they fall into three general classifications. The first type relates to energy which presumably is the motivating force for rumen bacteria to attach or digest compounds such as cellulose. The second type of nutrient needed by rumen microorganisms relates to protein or the elements such as nitrogen which are eventually synthesized into protein material. The third type of nutrients appear to be inorganic in nature and are believed to be integral constituents in enzymes or enzyme systems as well as vitamins synthesized by rumen microorganisms.

The eventual specific enumeration of nutrient requirements of these organisms along with the amounts of such nutrients furnished by different roughages and other feeds may be of considerable economic importance in the feeding of cattle and other cud-chewing farm animals. The artificial rumen technique offers one means of studying these specific nutrient requirements and the availability of such constituents in various feeds. Since this technique is relatively new it would seem profitable to discuss briefly some of its apparent advantages and limitations at this time.

The chief advantage of the artificial rumen appears to be the speed with which determinations can be carried out in a series of laboratory flasks as compared with similar determinations carried out in the rumens of live animals. This is of importance primarily because of the large number of factors involved in the efficiency with which rumen microorganisms contribute to the nutrition of the host animal.

Another advantage of the artificial rumen is the precision which can be exercised over various conditions in the laboratory which are left to change

in experimental studies using live animals. This finds particular importance when one considers the possible variations which can occur from time to time in the rumen of a single animal which are further multiplied when comparative studies are made using a series of animals. The greater precision obtained in laboratory studies is more evident when one considers the limitations in making quantitative measurements within the rumen of cattle or sheep. These limitations arise primarily because the rumen is not a closed system; instead, materials are constantly passing out either into the remainder of the digestive tract or by absorption directly into the blood stream. Also, saliva more-or-less constantly flows into the rumen irrespective of whether the animal is eating or consuming water.

A third advantage of the artificial rumen over rumen studies with live animals involves the expense of experimentation. Not only is the expense of caring for and feeding animals greatly reduced, but the amounts of different feeds or feed ingredients needed in laboratory studies are very small indeed. This becomes quite important in fundamental studies using synthetic types of feeds which become almost prohibitive to use in larger animals.

Conversely there are limitations in the experimental use of artificial rumens compared with studies in ruminant animals. Foremost of these limitations is the disadvantages which generally occur in *in vitro* studies as compared with *in vivo* measurements. There is always doubt in *in vitro* experimentation as to whether the conditions set-up in the laboratory are truly representative of the conditions which occur under natural conditions in the live animal. For example, the feeding habits of an animal often are spread over a considerable part of a day whereas feeds are introduced all at one time in the artificial rumen. This artificial condition approximates the natural condition but the difference involved may or may not have importance. Other approximations must be made in the artificial rumen such as the addition of chemical constituents which appear similar to saliva. Also, the manner of controlling end products of fermentation such as organic acids is only approximated in *in vitro* studies. Still another factor relates to the types of microorganisms which develop in the artificial rumen as compared to the flora maintained in a rumen proper.

The above limitations of the artificial rumen technique are doubtlessly incomplete and any interpretation placed upon results obtained by these methods must be tempered with reservations embodying such limitations. Nevertheless there is considerable evidence indicating that these limitations are of minor importance and that the approximations made to rumen conditions in the laboratory flasks are, for the most part, satisfactory. Perhaps the strongest evidence to date supporting this contention is the ability to

maintain over long periods of time high degrees of cellulose digestion in artificial rumens which compare favorably with the degree of cellulose digestion which occurs in cattle and sheep.

It would seem that the artificial rumen can best be used as a screening device in studying influential factors of feeds in rumen physiology, from which the most promising results must be ultimately checked in animal experimentation.

Summary

Four poor quality roughages—corn stover, wheat straw, corncobs, and mature timothy-blue grass hay—were compared in *in vitro* cellulose digestion studies with four good quality dehydrated forages—clover hay, rye hay, and two shipments of alfalfa hay, respectively. Supplements—including available nitrogen, a complex mineral mixture, and an autoclaved water extract of cow manure—each of which proved beneficial to the digestion of filter paper cellulose in control studies, were added singly and in combination to each of the good and poor quality roughages. The cellulose in the good quality roughages was digested efficiently without supplementation, digestion being as good as that occurring when the additions of complex minerals and autoclaved manure extract were included. Conversely, the cellulose in the poor quality roughages failed to be digested efficiently without supplementation. The additions of complex minerals and manure extract along with available nitrogen greatly increased cellulose digestion in these poor quality roughages. The results were interpreted with respect to the advantages and limitations of the artificial rumen technique in determining the nutritive requirements of rumen microorganisms and the adequacies and inadequacies of natural feeds in supplying these nutrients.

Literature Cited

Burroughs, Wise and Paul Gerlaugh. 1949a. The Influence of Soybean Oil Meal upon Roughage Digestion in Cattle. JOURNAL OF ANIMAL SCIENCE 8: 3

Burroughs, Wise, Paul Gerlaugh, B. H. Edgington and R. M. Bethke. 1949b. Further Observations on the Effect of Protein upon Roughage Digestion in Cattle. JOURNAL OF ANIMAL SCIENCE 8: 9.

Burroughs, Wise, L. S. Gall, Paul Gerlaugh and R. M. Bethke. 1950a. The Influence of Casein upon Roughage Digestion in Cattle with Rumen Bacterial Studies. JOURNAL OF ANIMAL SCIENCE 9: 214.

Burroughs, Wise, Paul Gerlaugh and R. M. Bethke. 1950b. The Influence of Alfalfa Hay and Fractions of Alfalfa Hay upon the Digestion of Ground Corncobs. JOURNAL OF ANIMAL SCIENCE 9: 207.

Burroughs, Wise, Norma A. Frank, Paul Gerlaugh and R. M. Bethke. 1950c. Preliminary Observations upon Factors Influencing Cellulose Digestion by Rumen Microorganisms. Jour. Nutrition 40: 9.

CELLULOSE DIGESTION BY RUMEN MICROORGANISMS AS INFLUENCED BY CEREAL GRAINS AND PROTEIN-RICH FEEDS COMMONLY FED TO CATTLE USING AN ARTIFICIAL RUMEN[1]

WISE BURROUGHS, JOHN LONG, PAUL GERLAUGH AND R. M. BETHKE
Ohio Agricultural Experiment Station[2]

NUMEROUS communications from this laboratory, Burroughs *et al.* (1949a, 1949b, 1949c, 1950a, 1950b, and 1950c) have called attention to the influence of nutrients needed by rumen microorganisms in the digestion of roughages, particularly the cellulose fraction. Hungate (1950), after extensively reviewing the literature pertaining to rumen cellulose digesting bacteria, concluded that: "Further improvements (cellulose digestion) based on exact studies of the nutritional requirements of the rumen microorganisms appear highly desirable. In approaching the problem it should be kept in mind that the first step in ruminant nutrition is microbial nutrition."

The feeding of cattle and other ruminant animals often includes the feeding of grains and protein-rich feeds in combination with roughage. The possibility was presented that these grain and protein-rich feeds when fed with roughage might supply nutritional factors needed by rumen microorganisms in the digestion of the roughage fraction of the ration. The purpose of this paper is to present evidence that certain grain and protein-rich feeds contribute to the nutrition of cellulose-digesting rumen microorganisms.

Experimental Methods

Twelve artificial rumens were used simultaneously in two water baths as previously described, Burroughs *et al.* (1950c). Filter paper (1 gram) was introduced into each artificial rumen or laboratory flask every 36 hours over a 12-day period. Each flask was originally inoculated with 140 ml. of strained rumen liquid collected by stomach tube before the morning feeding of a steer receiving an all-alfalfa hay ration. At the end of each 36-hour period the flask contents were divided into two equal portions. One portion was analyzed for cellulose whereas the other portion served as inoculum for the succeeding 36-hour fermentation.

Three grains or protein-rich feeds were each studied simultaneously in respective series of three artificial rumens and compared with three control

[1] Published with the approval of the Director of the Ohio Agricultural Experiment Station. Supported in part by a Grant-in-Aid from Swift and Company, Chicago, Illinois.

[2] Department of Animal Science.

flasks containing filter paper but no supplemental feeds. In addition to filter paper and inoculum, the first control flask contained available nitrogen in the form of ammonium sulfate and sufficient distilled water to make a total of 350 ml. of fermentation material. The second flask was similar to the first except that a complex mineral mixture was added. Likewise, the third control flask was similar to the second except for the addition of 150 ml. of autoclaved water extract of cow manure. The ammonium sulfate, complex minerals, and autoclaved water extract of manure were prepared and added in amounts similar to the methods employed earlier, Burroughs *et al.* (1950c).

Each grain or protein-rich feed was added (1 gm. each 36-hour period) to each of three flasks containing the respective supplements of ammonium sulfate, complex minerals, and manure extract similar to the control flasks. The carbonaceous and protein-rich feeds are described in table 1 on the

TABLE 1—ANALYSIS OF FEEDS STUDIED

Feed	Moisture %	Protein (N×6.25) %	Ash %	Cellulose %
Dried distillers solubles	18.3	27.0	9.7	4.6
Linseed oil meal	8.8	35.1	5.5	11.4
Soybean oil meal	11.8	46.0	5.3	10.1
Dried skimmilk	9.6	32.4	7.8	0.0
Molasses (cane)	28.8	3.0	6.3	0.0
Corn (ground yellow)	14.4	7.9	1.1	1.8
Wheat bran	16.5	13.6	4.9	12.8
Cottonseed meal	9.7	41.8	5.9	9.5
Meat scraps	6.6	54.6	25.9	0.0
Fish meal	8.9	59.9	20.4	0.2
Liver meal	8.6	63.0	4.1	0.0
Oats (ground)	11.2	13.5	2.9	8.7

basis of analysis for moisture, protein (N×6.25), ash, and cellulose. Each feed was ground initially through the medium screen of a Wiley mill before analysis and introduction into the fermentation flasks.

The details of the fermentation technique, such as maintenance of temperature, hydrogen-ion concentration, methods of sampling, and chemical procedure for cellulose analysis were similar to methods described in previous experiments, Burroughs *et al.* (1950b and 1950c). The same was true with respect to bacteriological examinations including Gram stains and observations for the presence of protozoa.

Results and Discussion

The cellulose digestion coefficients obtained are presented in table 2. The four series of filter paper control flasks, each series containing respective

additions of ammonium sulfate, ammonium sulfate plus complex minerals, and ammonium sulfate plus complex minerals plus autoclaved manure extract gave results similar to those reported earlier. Very little cellulose digestion occurred beyond the first or second 36-hour periods with only the available form of nitrogen added to the filter paper. Upon adding complex minerals in addition to ammonium sulfate, cellulose digestion was materially better, however, there was a more-or-less continuous decrease in digestion as the 36-hour periods progressed. Adding autoclaved manure extract along with the two above supplements resulted in efficient cellulose digestion throughout the 12 days of each experiment.

The data of each of the four series of three control flasks are distributed throughout table 2 in which the three comparable feed series (three flasks each) immediately follow. Comparing flasks with only available nitrogen, those containing feeds plus filter paper were in some instances better than the control flasks containing only filter paper. This was true with additions of dried distillers solubles, linseed oil meal, soybean oil meal and to a slight extent in the case of meat scraps. Dried skimmilk, molasses, corn, wheat bran, cottonseed meal, fish meal, liver meal, and oats each essentially failed to stimulate cellulose digestion in flasks containing only ammonium sulfate.

Comparing artificial rumens with and without feed supplements in the presence of filter paper and with both available nitrogen and complex minerals, a large percentage of the feeds tested stimulated cellulose digestion. In fact the only feeds failing to stimulate cellulose digestion under this set of conditions were meat scraps, fish meal, liver meal, and oats.

Another comparison in table 2 shows the influence of different feeds upon cellulose digestion in flasks containing autoclaved manure extract in addition to available nitrogen and complex minerals. Under these conditions only a few of the feeds tended to stimulate cellulose digestion and these to a minor extent with the possible exception of dried distillers solubles.

The results presented in table 2 are summarized further in table 3 which permits comparisons of feeds as to their influence upon cellulose digestion. The method of computing the summarized figures in table 3 was based upon the average cellulose digestion during the last four 36-hour fermentation periods. The stimulating effect of a feed upon cellulose digestion was assigned a numerical value representing the difference obtained by subtracting the percentage cellulose digestion in a control flask from the percentage cellulose digestion in a flask similar except for the addition of a cereal grain or a protein-rich feed.

The feeds in table 3 are arranged approximately in a descending order with respect to their stimulating influence upon cellulose digestion. On this basis, dried distillers' solubles, linseed oil meal, and soybean oil meal appeared to exert the strongest influence. Dried skimmilk, molasses, corn,

TABLE 2. PERCENTAGE CELLULOSE DIGESTION BY RUMEN MICRO-ORGANISMS AS INFLUENCED BY CEREAL GRAINS AND PROTEIN-RICH FEEDS USING AN ANTIFICIAL RUMEN

Flask description	36-hour fermentation period								
	1	2	3	4	5	6	7	8	Aver. last 4
Control flasks with filter paper only—First experiment									
Nitrogen only	71	21	1	2	−6	3	1	1	0
Complex minerals+N	80	31	39	42	12	6	10	2	8
Manure extract+Mnrls.+N	83	71	55	84	79	63	78	57	70
Ground corn with filter paper									
Nitrogen only	77	21	0	4	−1	−4	3	0	0
Complex minerals+N.	85	56	90	42	50	44	31	49	44
Manure extract+Mnrls.+N	83	58	78	77	67	94	70	86	79
Soybean oil meal with filter paper									
Nitrogen only	82	40	57	34	30	39	36	19	31
Complex minerals+N	85	63	70	83	60	61	57	73	63
Manure extract+Mnrls.+N	85	64	86	69	80	77	67	82	76
Meat scraps with filter paper									
Nitrogen only	77	30	34	19	19	12	15	5	13
Complex minerals+N	82	32	20	3	9	6	6	18	10
Manure extract+Mnrls.+N	79	63	83	79	74	95	65	92	82
Control flasks with filter paper only—Second experiment									
Nitrogen only	56	8	1	3	2	0	2	0	1
Complex minerals+N	77	59	44	59	49	29	2	2	20
Manure extract+Mnrls.+N	86	43	84	80	91	60	87	89	82
Molasses with filter paper									
Nitrogen only	70	18	−3	4	1	0	1	3	1
Complex minerals+N	82	90	42	88	71	75	66	74	72
Manure extract+Mnrls.+N	89	86	79	94	90	93	89	82	88
Cottonseed meal with filter paper									
Nitrogen only	58	14	22	17	3	2	1	3	2
Complex minerals+N	67	51	43	61	70	30	64	10	44
Manure extract+Mnrls.+N	81	79	69	84	72	84	77	80	77
Liver meal with filter paper									
Nitrogen only	45	6	2	−1	6	−1	2	0	2
Complex minerals+N	69	13	2	11	1	1	1	−2	0
Manure extract+Mnrls.+N	82	80	69	89	71	89	74	74	77
Control flasks with filter paper only—Third experiment									
Nitrogen only	69	28	3	1	0	0	2	0	0
Complex minerals+N	82	40	58	60	25	31	12	16	21
Manure extract+Mnrls.+N	86	33	87	13	19	60	78	75	58

TABLE 2.—*Continued*

Flask description	36-hour fermentation period								
	1	2	3	4	5	6	7	8	Aver. last 4
Dried distillers solubles with filter paper									
Nitrogen only	63	58	7	2	22	86	−17	21	28
Complex minerals+N	82	59	88	61	85	85	62	62	74
Manure extract+Mnrls.+N	86	44	93	93	65	96	90	89	85
Linseed oil meal with filter paper									
Nitrogen only	60	66	16	89	19	41	43	55	40
Complex minerals+N	77	77	62	71	58	60	53	70	60
Manure extract+Mnrls.+N	83	35	82	25	84	72	75	45	69
Dried skimmilk with filter paper									
Nitrogen only	66	44	6	6	8	6	4	−2	4
Complex minerals+N	82	66	68	91	42	65	67	81	64
Manure extract+Mnrls.+N	84	53	84	90	30	85	84	51	63
Control flasks with filter paper only—Fourth experiment									
Nitrogen only	76	0	3	−2	4	4	3	4	.1
Complex minerals+N	30	21	26	20	20	1	5	1	1
Manure extract+Mnrls.+N	78	82	74	54	63	74	70	58	66
Ground oats with filter paper									
Nitrogen only	56	6	0	2	3	2	3	9	4
Complex minerals+N	66	58	30	43	34	10	2	1	12
Manure extract+Mnrls.+N	68	65	48	73	65	42	38	44	47
Wheat bran with filter paper									
Nitrogen only	72	26	1	3	3	4	2	7	4
Complex minerals+N	76	63	71	53	25	41	50	52	42
Manure extract+Mnrls.+N	76	60	78	74	57	72	69	85	71
Fish meal with filter paper									
Nitrogen only	84	45	0	2	1	7	−2	1	3
Complex minerals+N	44	27	5	1	0	3	2	7	3
Manure extract+Mnrls.+N	77	79	68	55	79	81	66	80	76

wheat bran, and cottonseed meal represented feeds having an intermediate helpful influence upon cellulose digestion. Feeds exerting little or no helpful influence upon cellulose digestion were meat scraps, fish meal, liver meal, and ground oats.

Discussion

The results indicate rather strongly that certain cereal grains and protein-rich feeds influence the microbiological digestion of cellulose. There is also

evidence that the method by which these influences are brought about is through the nutrients which these feeds supply to cellulose-splitting rumen microorganisms.

The amounts of these nutrients needed by rumen microorganisms and found in various feeds cannot be determined with a high degree of accuracy with the data presented in this paper. At best the arbitrary values in table 3 are approximations made on a single source of each of the various feeds.

TABLE 3. RELATIVE POTENCY OF FEEDS STIMULATING CELLULOSE DIGESTION IN *IN VITRO* FERMENTATION WITH RUMEN MICROORGANISMS

Feeds studied	Available nitrogen comparison[1]	Complex minerals+ nitrogen[2]	Autoclaved manure+minerals +nitrogen[3]
Dried distillers' solubles	28	53	27
Linseed oil meal	40	39	11
Soybean oil meal	31	55	6
Dried skimmilk	0	43	0
Molasses (cane)	0	52	0
Ground corn	0	36	9
Wheat bran	0	35	5
Cottonseed meal	0	24	0
Meat scraps	13	0	12
Fish meal	0	9	10
Liver meal	0	Neg.	0
Ground oats	0	0	Neg.

[1] Each figure in column 1 represents the percentage difference in cellulose digestion between a control flask containing available nitrogen and an experimental flask similar in all respects except for the addition of a respective feed.

[2] The figures in column 2 were computed similar to those in column 1; however, both the control and experimental flasks contained a complex mineral mixture in addition to available nitrogen.

[3] Likewise, the figures in column 3 were similarly computed but both the control and experimental flasks contained autoclaved manure liquid in addition to the complex mineral mixture and available nitrogen.

There is a possibility that different sources of any given feed may give values with considerable variation.

Even if the values obtained in table 3 should prove to be average and representative of each feed, the results cannot be immediately translated into feeding practice without animal experimentation for several reasons. Foremost of these reasons is the complexity of different sources of nutrients which are utilized by rumen microorganisms. Whenever a cereal grain or protein-rich feed is fed to cattle or sheep it is fed with some form of roughage. Thus the roughage not only supplies cellulose and other sources of energy for rumen microorganisms but it supplies other nutrients in addition, Burroughs *et al.* (1950c). These other nutrients in roughage along with the

demonstrated nutrients in concentrate feeds would be expected to furnish a different nutrient mixture for rumen flora as compared with such nutrients being derived solely from the concentrate feed.

There are still other sources of nutrients for microorganisms living within the rumen than those in the feeds consumed. One source is the saliva which continually enters the rumen. Saliva not only contains buffering salts to neutralize organic acids formed in fermentation but it contains minerals useful to the nutrition of rumen micro-flora (unpublished data). Similar or different mineral nutrients enter the rumen when water is consumed and when animals come in contact with soil and various other materials incidentally picked up and not regarded as ration in gredients. Such materials, especially drinking water and soil, may at times be quite important to the nutrition of rumen microorganisms.

Despite the limitations of the present data for immediate application in feeding practice, there is reason to believe that information of this type will form a sound basis for animal experimentation which eventually may have many practical applications in cattle and sheep feeding. For example, it is interesting to recall that feeding practices of cattle two decades ago in this country, especially dairy animals, made use of rather complex concentrate feed mixtures. These feeding practices for the most part were based upon well-planned experimental work. During the past decade there has been more and more of a tendency in dairy cattle feeding to make use of simple types of concentrate mixtures. This tendency also appears to be based on well-planned experimental work. It would seem that these apparent discrepancies in recommended feeding practices between the two periods might well be explained on the basis of nutrient requirements of rumen microorganisms and the differences in adequacies or inadequacies of feeds being used in the two periods in meeting these nutrient requirements. During the past 10 or 15 years, which coincides with the tendency to feed the more simply-compounded grain mixtures, the importance of vitamin A in dairy cattle nutrition has been demonstrated. The supplying of adequate vitamin A or carotene in non-pasture seasons to dairy cows has placed emphasis upon the importance of feeding higher quality roughages. The possibility exists that these higher quality roughages have been used in recent years in which the simpler concentrate mixtures have proved effective whereas earlier results which appeared more favorable to the complex mixtures were experimentally-tested using poorer quality roughages.

Proof of the above reasoning requires animal experimentation or more specifically experiments with dairy cattle designed to test if the quality of roughage being fed is the determining influence as to whether the complexity of the dairy grain mixture has importance in feeding practice. The use

of the artificial rumen cannot by itself answer this type of problem. It is the contention of the authors that the artificial rumen can serve best as a screening device for developing this type of concept whose actual application must eventually be tested with animal experiments.

Summary

Nine feeds, including cereal grains and protein-rich feeds, were tested with respect to their ability to stimulate rumen microorganisms in the digestion of cellulose. Three control flasks or artificial rumens were used containing filter paper and one, two, or three of the following supplements: ammonium sulfate, complex minerals, and autoclaved water extract of manure. Cellulose digestion in the control flasks was compared with that in three flasks which were similar except for the addition of the feed being studied. The results indicated that many feeds influence rumen microorganisms favorably in cellulose digestion. Dried distillers solubles, soybean oil meal, and linseed oil meal appeared most helpful under the experimental conditions imposed. These were followed by cane molasses, corn, wheat bran, and cottonseed meal. Feeds showing little or no favorable influence upon rumen micro-biological digestion were meat scraps, fish meal, liver meal, and oats.

Literature Cited

Burroughs, Wise and Paul Gerlaugh. 1949a. The Influence of Soybean Oil Meal upon Roughage Digestion in Cattle. JOURNAL OF ANIMAL SCIENCE 8: 3.

Burroughs, Wise, Paul Gerlaugh, B. H. Edgington and R. M. Bethke. 1949b. Further Observations on the Effect of Protein upon Roughage Digestion in Cattle. JOURNAL OF ANIMAL SCIENCE 8: 9.

Burroughs, Wise, Paul Gerlaugh, B. H. Edgington and R. M. Bethke. 1949c. The influence of Corn Starch Upon Roughage Digestion in Cattle. JOURNAL OF ANIMAL SCIENCE 8: 271.

Burroughs, Wise, Paul Gerlaugh and R. M. Bethke. 1950a. The Influence of Alfalfa Hay and Fractions of Alfalfa Hay Upon the Digestion of Ground Corncobs. JOURNAL OF ANIMAL SCIENCE 9: 207.

Burroughs, Wise, Norma A. Frank, Paul Gerlaugh and R. M. Bethke. 1950b. Preliminary Observations Upon Factors Influenceing Cellulose Digestion by Rumen Microorganisms. Jour. Nutr. 40: 9.

Burroughs, Wise, H. G. Headley, R. M. Bethke and Paul Gerlaugh. 1950c. Cellulose Digestion in Good and Poor Quality Roughages using an Artificial Rumen. JOURNAL OF ANIMAL SCIENCE 9:513.

Hungate, R. E. 1950. The Anaerobic Mesophilic Cellulolytic Bacteria. Bacteriological Reviews 14: 1.

SOME EFFECTS OF FORAGE COMPOSITION ON ITS NUTRITIVE VALUE WHEN CUT AND FED GREEN TO STEERS AND WETHERS, AS DETERMINED CONVENTIONALLY AND BY THE LIGNIN RATIO[1]

R. M. Forbes[2] and W. P. Garrigus
Kentucky Agricultural Experiment Station

REFERENCE has been made in previous reports (Forbes and Garrigus, 1948, 1950) to the literature dealing with the use of the lignin ratio as a method for calculation of digestibility of feeds by ruminants, and our investigations relating to grazing animals have been described in detail. This paper presents more detailed results of our digestion experiments with steers and wethers, compares the results obtained by grazing and by digestion trial procedures, and reports the metabolizable energy value of a number of forages cut and fed green to wethers.

Experimental

The experimental animals and forages used are described by Forbes and Garrigus (1950). The techniques employed in the conduct of the digestion trials have been described in detail (Forbes and Garrigus 1948), and have been modified only slightly for purposes of convenience and in attempts to gain greater accuracy. During the 1948 season all feces samples for analysis were preserved by freezing until aliquotting was done. During the 1949 season steer feces were preserved by freezing and wether feces were preserved by drying the daily samples separately so as to facilitate interpretation of daily variation in dry matter output.

Chemical analyses of forages and of feces were made by accepted procedures. In the chemical analysis of isolated lignin, nitrogen was determined by Kjeldahl procedure and methoxyl by the method of Clark (1943).

Calculations of digestibility were made by conventional and by lignin-ratio methods. The metabolizable energy of the forages was calculated by the method described by Forbes and Garrigus (1949).

Results and Discussion

The results obtained by use of steers and of wethers are presented separately to make possible a more orderly discussion. In table 1 and figure 1 are

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the director.

[2] Formerly Associate Professor of Animal Husbandry, University of Kentucky, now Associate Professor of Animal Nutrition, University of Illinois.

TABLE 1. COMPOSITION OF DRY MATTER OF FORAGES AND DIGESTION COEFFICIENTS OBTAINED WITH STEERS BY CONVENTIONAL AND BY LIGNIN RATIO METHODS

Trial	Composition of dry matter						Method	Digestion coefficients					
	Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Organic matter		Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Organic matter
Blue-grass 1	19.2	5.7	22.1	46.6	3.9	93.6	Conv.	77	69	81	82	−11	80
							L.R.	79	72	83	84	—	82
Blue-grass 2	14.3	4.4	29.0	46.9	6.9	94.6	Conv.	71	65	74	70	6	72
							L.R.	69	63	73	69	—	70
Blue-grass 3	16.2	5.7	27.5	44.1	6.0	93.5	Conv.	74	62	70	69	− 4	70
							L.R.	75	63	71	71	—	71
Blue-grass 4	12.4	4.4	27.3	50.4	7.1	94.5	Conv.	65	57	65	65	− 7	65
							L.R.	67	59	67	68	—	67
Blue-grass 5	12.9	4.4	30.0	47.3	9.1	94.6	Conv.	63	57	62	60	1	61
							L.R.	62	58	61	59	—	60
Blue-grass 6	11.8	4.6	27.7	49.3	7.9	93.4	Conv.	62	47	63	61	2	61
							L.R.	62	46	63	61	—	61
Blue-grass 7	11.7	4.7	30.3	47.3	9.0	94.0	Conv.	54	43	62	51	− 9	55
							L.R.	58	47	65	55	—	58
Alfalfa	22.4	4.3	21.7	43.8	6.7	92.2	Conv.	80	39	50	75	− 9	69
							L.R.	81	44	55	77	—	71
Orchard Grass	14.5	5.8	25.8	45.9	5.3	92.0	Conv.	69	62	74	74	−18	72
							L.R.	74	68	78	78	—	77
Ky. 31 Fescue	12.6	4.0	28.5	47.9	7.4	93.0	Conv.	67	62	68	68	− 5	68
							L.R.	68	65	69	69	—	69

shown the average data obtained on each forage fed to steers. Three animals are represented in each average.

The digestion coefficients calculated by conventional and by lignin-ratio methods are reasonably close, as would be expected in view of the usually small error in lignin recovery, evidenced by an average negative digestion coefficient of 5%.

The most significant correlation between organic matter digestibility and forage composition is that related to the lignin content of the forage. In this respect the data are similar to those reported for grazing steers by Forbes and Garrigus (1950). The regressions of organic matter digestibility, Y, on lignin content, X, are, $Y = 95 - 4.10X$ for conventional calculations

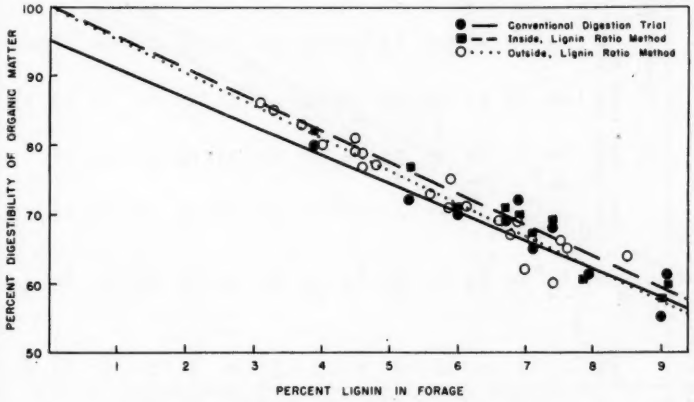

Figure 1. Digestibility of forages consumed by steers.

and $Y = 100 - 4.53X$ for calculations made by lignin ratio. These are statistically similar to the equation previously obtained and reported, $Y = 100 - 4.71X$, by use of the lignin-ratio method in trials with grazing steers (Forbes and Garrigus 1950), and are not in themselves statistically different as shown by the "t" test.

In the digestion trials the steers were fed six to eight pounds of dry matter daily, while in grazing trials they voluntarily consumed two to three times this amount. The similar digestive capacities exhibited over this wide range of intakes supports the view of Watson *et al.* (1935) that the digestibility of roughages is not influenced by the level of feed intake.

Table 2 and figure 2 show the average data on digestibility and metabolizability of forages cut and feed green to sheep in digestion stalls or in metabolism crates. Three to six animals are represented in each average.

The digestion coefficients for forages fed to wethers, determined by the

TABLE 2. COMPOSITION OF DRY MATTER OF FORAGES, DIGESTION COEFFICIENTS AND METABOLIZABLE ENERGY VALUES OBTAINED WITH WETHERS

Trial	Composition of dry matter						Method	Digestion coefficients							Metabolizable energy	
	Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Organic matter		Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Organic matter	Energy	Cal/Kg	% of digestible energy
Blue grass 1	12.5	4.1	27.3	50.4	7.1	94.3	Conv.	61	51	49	59	−16*	57			
							L.R.	66	58	56	69	—	62			
Orchard Grass 2	8.2	3.8	33.5	48.4	6.4	94.1	Conv.	61	54	62	63	−19*	62			
							L.R.	67	61	68	68	—	68			
Orchard Grass 5	12.7	6.6	27.3	45.7	7.1	93.4	Conv.	65	47	67	63	− 5	63	58	2220	83
							L.R.	67	49	69	64	—	66	60		
Orchard Grass 8	16.6	5.6	24.2	42.7	5.0	89.1	Conv.	76	49	72	69	−15	70	67	2330	76
							L.R.	79	56	76	73	—	74	71		
Ky. 31 Fescue 2	9.7	4.1	31.9	47.4	6.2	93.1	Conv.	61	70	66	70	− 7*	68			
							L.R.	63	72	68	72	—	70			
Ky. 31 Fescue 5	7.9	4.5	26.3	53.0	7.6	91.7	Conv.	33	45	51	50	−24*	49	46	1700	80
							L.R.	46	56	60	60	—	59	57		
Ky. 31 Fescue 8	16.4	3.9	24.2	44.1	5.9	88.6	Conv.	73	62	65	62	−12	65	62	2050	75
							L.R.	27	66	69	66	—	69	66		
Lincoln Brome-grass 6	16.4	4.7	28.3	42.7	4.4	92.1	Conv.	81	58	78	75	−13	76	73	2460	75
							L.R.	82	62	80	78	—	79	75		
Timothy 3	5.5	3.1	33.5	53.8	11.7	95.9	Conv.	42	49	52	57	11	54	50	1750	75
							L.R.	34	43	46	51	—	48	44		
Ladino 1	23.1	8.6	15.3	43.7	4.1	90.7	Conv.	80	76	37	79	−44*	72			
							L.R.	86	83	58	86	—	81			
Ladino 5	23.6	6.7	17.2	45.7	5.6	93.2	Conv.	80	68	57	84	−17	77	74	2720	79
							L.R.	83	72	63	87	—	80	78		
Alfalfa 4	21.3	4.6	22.0	45.8	7.0	93.7	Conv.	76	47	45	70	−27	64	61	2210	77
							L.R.	81	57	56	76	—	71	69		
Alfalfa 6	22.3	6.0	17.8	45.9	6.1	92.2	Conv.	78	49	42	73	−15	67	64	2330	78
							L.R.	81	56	49	76	—	70	69		
Alfalfa 9	20.7	1.8	28.2	41.1	7.4	91.8	Conv.	79	−13	57	75	1	69	67		
							L.R.	79	−14	56	75	—	69	67		

* Lambs bedded on wood shavings.

two methods of calculation, are not in such good agreement as are those shown for steers due to the less satisfactory apparent digestion coefficients for lignin.

The regressions of organic matter digestibility on lignin calculated by the two methods are $Y = 98 - 5.32X$, and $Y = \text{?}1 - 4.92X$ for conventional and for lignin-ratio methods of calculation, respectively. These equations fall on either side of the equation similarly calculated from grazing wether data $Y = 100 - 5.24X$ (Forbes and Garrigus, 1950), and all three equations are statistically similar according to the "t" test. In making the above calculations from the digestion trial data, the timothy data have been excluded

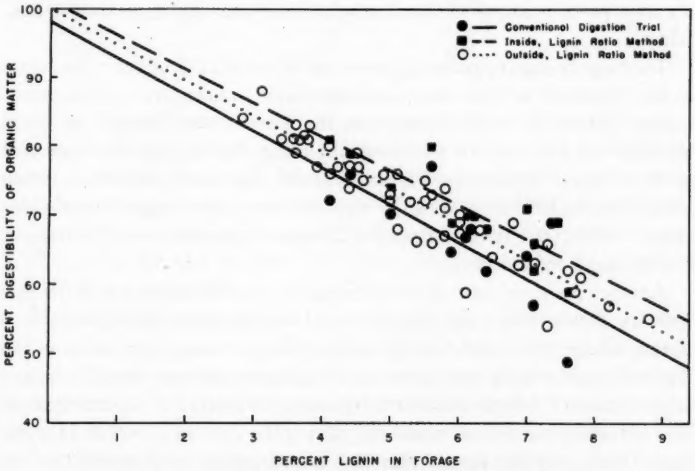

Figure 2. Digestibility of forages consumed by wethers.

since they markedly distort the regression lines. Justification for this exclusion is derived from the high lignin content of the timothy (11.7%) and on the basis of findings by other investigations, Forbes *et al.* (1946), Forbes and Garrigus (1949), Corbin (1947), and Ellis, Matrone and Maynard (1946), which show that in the rations investigated, containing over 10% lignin, the relationship between lignin content and dry matter digestibility, observed with lower lignin values, is no longer linear. An explanation for the deviation from the linear relationship in high-lignin forages may be found in the histo-chemical studies of Drapala *et al.* (1947), who have shown that early lignification involves a spreading of the area of lignification and that later maturity is better characterized by a denser lignification of previously lignified cell walls. It seems probable that the latter type of lignification increase would affect digestibility to a lesser degree than the former.

• Lambs bedded on wood shavings.

The metabolizable energy values given in table 2 were calculated by subtracting from the digestible energy the energy of the urine, corrected for change in nitrogen balance, and the energy of methane; the latter figure was calculated from digestible carbohydrate by the formula of Swift *et al.* (1948). The variation in the ratio of metabolizable energy to digestible energy may be traced most significantly to variation in the ratio of digestible carbohydrate to digestible energy in the forages. The correlation coefficient between these ratios is −.83. If the theory is accepted that the relative amount of digestible carbohydrate in a ration is the major factor determining the metabolizability of the ration, more urgency is thrown on the problem of accurate partitioning of the feed carbohydrates and studies of their utilizability.

The large average negative digestion coefficient of 14% obtained for lignin in the trials with wethers, was a consistent source of concern in these experiments. During the early experiments the animals were bedded on wood shavings and some animals were seen nibbling at the shavings. This appeared to be a logical explanation for the negative digestion coefficients, which should be avoidable by putting the wethers in properly designed metabolism crates. Subsequent results showed a distinct improvement in this respect but left much to be desired.

Another point to come under investigation was the adequacy of the preliminary period. Since each digestion trial was preceded by a grazing trial during which the animals usually ate much more forage than when in the digestion crates, daily dry matter excretion measurements were made in a large number of trials to discover the presence or absence of a trend of excretion indicating the loss of extra "fill" during the collection period. In a few cases these daily dry matter excretion measurements were started on the day the animals were placed in the metabolism crates. In all cases the preliminary period of five to seven days on constant feed intake, added to at least four days of build-up period on the same forage, was adequate for removal of the extra fill. In a separate experiment, the change in feces-lignin content was measured when wethers were abruptly changed from a ration of high-lignin alfalfa hay to one of low-lignin ladino hay. From an average feces-lignin percentage of 22 the value decreased regularly to a constant percentage of 16, both measured on the dry matter basis, in an average of five days; the range for six animals was from four to six days. These observations indicate that the preliminary periods used were of adequate length.

Previous investigators have reported some chemical changes in lignin as it passes through the digestive tract of ruminants. Csonka (1929) reported a loss of methoxyl group, Pazur *et al.* (1948) showed an increased excretion of aromatic acids in the urine of sheep fed increased amounts of lignin, and Bondi and Meyer (1948) have shown that lignin isolated from forages

TABLE 3. METHOXYL CONTENT OF LIGNIN FROM FORAGE AND FROM FECES

Forage fed	Percent methoxyl in lignin of:		Ratio A/B
	A. Forage	B. Feces	
Fescue	10.10	10.31	.98
Orchard Grass	8.86	10.32	.86
Bluegrass	8.80	9.49	.93
Orchard Grass	6.15	5.56	1.10
Orchard Grass	6.23	6.11	1.02
Fescue	8.32	8.52	.98
Alfalfa	9.77	8.57	1.14
Ladino	5.74	5.31	1.08
Alfalfa	9.58	9.61	.99

yields up to 20% of its weight as aldehydes when treated with nitrobenzene in alkali, but that lignin isolated from feces yielded no aldehydes when so treated. Bondi and Meyer also found a slight increase in nitrogen but no change in methoxyl content of lignin isolated from feces as compared to that isolated from forages. Their isolations were not quantitative, but employed solution of lignin in alcoholic alkali as a means for obtaining as pure a lignin as possible.

We have made some attempts to ascertain whether the material analyzed as lignin in forages and in feces by the 72% H_2SO^4 method was chemically similar. The nitrogen content of lignin isolated from six forages and the feces of three animals fed each forage was determined by the Kjeldahl procedure, using $CuSO^4$ as a catalyst. The nitrogen content of feces lignin, with an average of 3.14% nitrogen, was higher in all but one instance than that of forage lignin, whose average nitrogen content was 2.40%. These values are lower than those reported by Sowden and DeLong (1949) but are similar to those reported by Bondi and Meyer (1948). If it is assumed that the nitrogen present in the isolated lignin is a protein impurity, and the lignin values are correspondingly corrected for protein content, some improvement is made in digestion coefficients but the average coefficient is still significantly negative. In the first ladino clover trial the feces lignin contained 1.6% nitrogen while the clover lignin contained nearly 2.5% nitrogen. This might be explained if the animals excreted a large share of the lignin from wood shavings, which lignin is reported by Bondi and Meyer to contain much less nitrogen than does lignin from pasture plants.

Since the forages studied were rather low in lignin content, and such lignin has a low methoxyl percentage, it appeared possible that methoxylation of lignin in the digestive tract of the sheep might account for the "extra" lignin excreted. Table 3 shows that in nine trials involving 27 individual

TABLE 4. RELATIONSHIP BETWEEN LIGNIN AND LIGNIN METHOXYL YIELDS IN DUPLICATE SAMPLES

Sample	Lignin %	Methoxyl in lignin %	Lignin methoxyl per gm. of sample (mg)
1a	6.3	8.85	5.58
b	6.9	7.70	5.31
2a	5.2	10.10	5.25
b	7.2	7.47	5.38
3a	9.2	6.50	5.98
b	6.8	8.87	6.03
4a	3.7	5.20	1.92
b	3.0	6.70	2.01
5a	17.2	10.07	17.30
b	18.8	9.13	17.20

comparisons, the average ratio of methoxyl in forage lignin to that in feces lignin was $1.02 \pm .088$. These data indicate that apparently there is no extensive change in methoxyl content of forage lignin in the digestive tract of the sheep. This is in agreement with the findings of Bondi and Meyer.

The variability found in methoxyl content of related forage and feces lignin is probably a result of variation in the lignin analyses. It was observed that when duplicate analyses varied widely, the methoxyl percentage was low in that member of the pair having the higher apparent lignin content, thus indicating that the discrepancy was due to a failure to remove non-lignin organic matter in the course of the analysis. The data in table 4 illustrate this point and show that the lignin methoxyl per gram of sample was quite constant as a result of the inverse relationship between lignin and percent methoxyl in lignin. While variations between duplicate lignin analyses as shown in table 4 are not usual, such a variation may be seen all too often if the same sample is analyzed at different times. It would appear that there is some unknown variable affecting the lignin analysis.

In spite of the variable and negative digestion coefficients found for lignin, it appears that this method is useful in determining relative digestibilities among forages of different species or of the same species at various growth stages. Additional research needs to be done on the method of analysis, with particular attention being paid to elimination of nitrogenous materials from the lignin residue.

Summary

From the results of digestion and metabolism experiments, employing steers and wethers, in which calculations were made by conventional and by lignin-ratio methods, the following observations may be made:

1. Variation in organic-matter digestibility is most closely associated with the lignin content of the forage.

2. Regression equations expressing the relationship of lignin content to organic-matter digestibility are statistically similar whether calculated from conventional or lignin-ratio data from digestion trials, or from grazing experiments employing the lignin-ratio method of calculation.

3. The percentage of digestible energy of green forages that is metabolizable varies most consistently with the digestible carbohydrate content of the forage.

4. Significant negative digestion coefficients for lignin are usually found when green forages are fed to steers and wethers and the lignin is analyzed by the method of Ellis, Matrone and Maynard.

Literature Cited

Bondi, A. and H. Meyer 1948. Lignins in Young Plants. Biochem. Jour. 43: 248.

Clark, E. P. 1943. Semi-Micro Quantitative Organic Analysis. Academic Press, New York, p. 68.

Corbin, J. E. 1947. Thesis, University of Kentucky.

Csonka, F. A., M. Phillips and D. B. Jones. 1929. Studies on Lignin Metabolism. Jour. Biol. Chem. 85: 65.

Drapala, W. J., L. C. Raymond and E. W. Crampton 1947. Pasture Studies XXVII. The Effects of Maturity of the Plant and Its Lignification and Subsequent Digestibility by Animals as Indicated by Methods of Plant Histology. Sci. Agr. 27: 36.

Ellis, G. H., G. Matrone and L. A. Maynard. 1946. A 72% H_2SO_4 Method for the Determination of Lignin and its Use in Animal Nutrition Studies. JOURNAL OF ANIMAL SCIENCE 6: 285.

Forbes, E. B., R. F. Elliott, R. W. Swift, W. H. James and V. F. Smith. 1946. Variation in Determination of Digestive Capacity of Sheep. JOURNAL OF ANIMAL SCIENCE 6: 298.

Forbes, R. M. and W. P. Garrigus. 1948. Application of a Lignin Ratio Technique to the Determination of the Nutrient Intake of Grazing Animals. JOURNAL OF ANIMAL SCIENCE 7:373.

Forbes, R. M. and W. P. Garrigus. 1949. The Digestibility and Metabolizability by Lambs of a Standard Ration of Alfalfa and Corn and One Containing Cottonseed Hulls. Jour. Agr. Res. 78: 483.

Forbes, R. M. and W. P. Garrigus. 1950. Some Relationships Between Chemical Composition, Nutritive Value, and Intake of Forages Grazed by Steers and Wethers. JOURNAL OF ANIMAL SCIENCE 9: 354.

Pazur, J. A. and W. A. DeLong. 1948. Pasture Studies XXVIII. Effect of Lignin Content and of Stage of Maturity of Dry Clover Forage on the Urinary Excretion of Aromatic Acids by Sheep. Sci. Agr. 28: 39.

Sowden, F. J. and W. A. DeLong. 1949. Pasture Studies XXIX. Investigations on the Lignin Fractions of Pasture Herbage and of the Feces of Ruminants. I. The Lignin Fraction of Pasture Herbage. Sci. Agr. 29: 409.

Sowden, F. J. and W. A. DeLong. 1949. Pasture Studies XXX. Investigations on the Lignin Fractions of Pasture Herbage and of the Feces of Ruminants. II. The Lignin Fraction of the Feces of Ruminants. Sci. Agr. 29: 418.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. 1948. The Effect of Dietary Fat on Utilization of the Energy and Protein of Rations by Sheep. JOURNAL OF ANIMAL SCIENCE 7: 475.

Watson, C. J., G. W. Muir and W. M. Davidson. 1935. Digestibility Studies with Ruminants. I. Plane of Nutrition and Digestibility of Hay. Sci. Agr. 15: 476.

THE SULFUR DIOXIDE PRESERVATION OF GRASS SILAGE[1,2]

C. B. KNODT

The Pennsylvania State College

IN RECENT years considerable emphasis has been placed upon grassland farming and particularly upon the production of grass silage. One of the important problems is that of the development of better methods of preservation of grass silage which will prevent the losses incurred. Reports from the Pennsylvania Station by McAuliffe (1942) and Stone *et al.* (1943) indicated the bacteriological and chemical changes which occur in grass silage prepared with several preservatives. Comparisons have also been made between grass silages prepared by various methods by Hegsted *et al.* (1939), Krauss and Washburn (1936) and Newlander *et al.* (1941). Glass jars and other containers have been used by Autrey *et al.* (1947), Garber and Odland (1927), Hunter and Bushnell (1916) and Odland *et al.* (1941) in experimental efforts to develop new methods of preservation.

This report presents experimental data obtained in the use of sulphur dioxide as a preservative for the preparation of grass silage.

Experimental Procedure

During early June of 1949 two tile silos of similar construction at the Montrose Experimental Farms were filled simultaneously with 40 tons silage each from a field of timothy-red clover. The crop was cut with a 4 foot tractor mower, wilted for 1 to 2 hours and then harvested with a field harvester and cut as short (about $\frac{1}{4}$ in.) as possible. Alternate loads were placed in each of the 2 silos so as to have the material as nearly alike in each as possible. In one, the silage was treated with 200 lbs. of hominy and in the other 5 lbs. of sulphur dioxide was used per ton of green material respectively. The hominy was added at the blower during unloading while the sulphur dioxide was added after every two and one-half to three feet of packed material had been put in the silo. Accurate weight of material going into the silos and the amounts of the respective preservatives required were kept. The gas was taken into the silo in 55 lb. drums and fed into the silage through a rubber hose attached to a brass rod. The brass rod was equipped with a brass disc 10 in. from the lower end as so to insure the SO_2 going in at the proper depth. The gas was injected into the silage every 2 feet in a circle 6 in. in from the

[1] The sulphur dioxide was supplied by the Virginia Smelting Co., West Norfolk, Virginia.

[2] Authorized for publication as paper No. 1603 in the Journal Series of The Pennsylvania Agricultural Experiment Station, on June 7, 1950.

side of the silo and then a circle was treated every 2 feet in until the entire area was covered. It was soon found that by inserting the rod, releasing the gas tank valve, counting to 10 and then shutting off the flow of gas, that close to the 5 lbs. per ton was added. At no time were the fumes from the gas a problem as it was absorbed rapidly by the silage.

Two groups of 10 cows each were selected so as to be similar in body weight, daily milk production and stage of lactation. Body weights were taken every 2 weeks as well as milk samples which were analyzed for milk fat. The cows were fed 30 lbs. of the respective silage for their particular group twice per day or a total of 60 lbs. per cow per day. In addition, they were fed 5 lbs. of No. 2 grade timothy-alfalfa hay and a 16 percent protein grain ration at the ratio 1 lb. of grain to 3.5 lbs. of milk per day. The amount of grain fed was changed every 2 weeks on the basis of the previous 3 days milk production. The cows were on their respective silages for a period of 8 weeks. No reversals were used because information was desired upon effects of length of feeding period upon the health of the cows. No ill effects were noted however as far as the health of the cows was concerned. The longest possible feeding period was wanted but was limited by the amount of silage prepared to the 56 days period. In addition, palatability trials were conducted with the materials.

The acidity was determined by the use of a Beckman industrial model potentiometer. Carotene was determined by the method of Moore and Ely (1941) using an Evelyn colorimeter. Analysis of variance were conducted by the methods of Snedecor (1946).

Results and Discussion

Surface spoilage

Four months after the silages were prepared the silos were opened. The amount of surface spoilage was similar in depth for both types of preservation. Other work has indicated, however, that surface spoilage can be cut in half by the use of sulphur dioxide particularly if larger amounts of the gas are used on the surface layer than the amount used in the silage prepared for this trial.

Palatability

There was no indication that palatability was a problem at any time. Several cows, not on the feeding trial reported here, were fed in excess of 80 lbs. of sulphur dioxide treated silage per day without any refusals. Cows which were given free choice of the 2 types of silages used in this work almost without exception ate the sulphur dioxide treated silage. The general appearance and palatability of the silage when removed from the silo was

very similar to that of the grass when cut in the field and there was no evidence of the sulphur dioxide being present after 4 months in the silo.

Preservation of carotene

A number of samples of the grass were taken, as the silage was prepared, at 16 hours and also as the silos were emptied 4 to 5 months later, for carotene analyses (table 1). It will be noted that approximately 3 times as much caro-

TABLE 1. THE PRESERVATION OF CAROTENE IN HOMINY AND SULPHUR DIOXIDE TREATED GRASS SILAGES

Time sampled	Type of silage	
	Hominy treated	Sulphur dioxide treated
	micrograms carotene per gram of dry matter	
As ensiled	208	215
16 hours	214	210
4 mo.	65	186
5 mo.	52	160

tene was preserved in the sulphur dioxide treated silage as in the hominy treated silages. While samples were analyzed 16 hours after filling, there were no differences in carotene content which were beyond analytical error. On the basis of these data it would appear that sulphur dioxide may decrease the oxidation of carotene which occurs in grass silage preservation.

Development of acidity

One of the important problems in grass silage preservation is that of the development of acidity. Acidity develops rapidly when sulphur dioxide is applied (table 2). It will be observed that adequate acidity developed within 16 hrs. after preparation for the preservation of the silage when this gas is used. The acidity had increased very little during the first 16 hours when

TABLE 2. THE DEVELOPMENT OF ACIDITY IN THE HOMINY AND SULPHUR DIOXIDE TREATED SILAGES

Time sampled	Type of silage	
	Hominy treated	Sulphur dioxide treated
	pH	
As ensiled	4.92	4.85
16 hrs.	4.76	4.05
4 mo.	4.15	4.10
5 mo.	4.04	4.00

hominy was used. Both silages were of good quality in terms of appearance and odor when taken from the silo 4 to 5 months after preservation as would be indicated by the pH of each at that time.

Effects on body weight of cows

Both groups gained weight consistently during the 8 weeks trial (from an average of 1243 to 1295 lbs. for the hominy treated group and from 1245 to 1289 for the SO_2 treated). While there was a small mean difference in body weight gains, this difference was not statistically significant.

Milk production

All cows used in the study were milked twice per day throughout the trial period. No statistically significant differences in milk production were found between the 3 groups of cows during the trial period (table 3). It

TABLE 3. AVERAGE DAILY MILK PRODUCTION OF COWS ON TRIAL

Days	Type of silage	
	Hominy grass silage	Sulphur dioxide grass silage
	lbs. 4% FCM	
−14– 0	42	42
1–14	40	41
15–28	40	42
29–42	38	41
43–56	37	39
Decline	5	3

will be noted that there was a decrease of 5 and 3 lbs. of 4% FCM respectively in the hominy-grass silage and sulphur dioxide-grass silage fed groups during the 8 weeks feeding period. On this basis it would appear that the feeding values of the 2 silages were quite similar even though 200 pounds of hominy had been added per ton to one of them. On this basis it would appear that very little fermentation occurred in the silage preserved with sulphur dioxide as compared to that in the hominy treated grass silage.

Summary

Grass silage prepared from timothy-red clover and preserved with 5 lbs. of sulphur dioxide per ton of green material was equal in feeding value in terms of milk production and gains in body weight of dairy cows to similar material preserved with 200 lbs. of hominy per ton of green material.

Because of the carotene content, palatability, ease of handling, feeding

value of silage preserved with it and low cost, it appears that sulphur dioxide may be of value in the preservation of grass silage.

Literature Cited

Autrey, K. M., C. B. Knodt and P. S. Williams. 1947. Grass and Legume Silage Studies Using 2-Quart Glass Jars as Miniature Silos. Jour. Dairy Sci. 30: 775.

Garber, R. J. and T. E. Odland. 1927. Mason Jars as Miniature Silos. Amer. Soc. Agron. Jour. 19: 259.

Hegsted, D. M., F. W. Quackenbush, W. H. Peterson, G. Bohstedt, I. W. Rupel and W. A. King. 1939. A Comparison of Alfalfa Silages Prepared by the A. I. V. and Molasses Methods. Jour. Dairy Sci. 22: 489.

Hunter, O. W. and L. D. Bushnell. 1916. Some Important Fermentations in Silage. Kans. Agr. Expt. Sta. Tech. Bul. 2.

Krauss, W. E. and R. G. Washburn. 1936. Studies on A. I. V. Silage. 3. Carotene Preservation and Biological Properties of the Milk. Jour. Dairy Sci. 19: 454.

McAuliffe, H. D. 1942. A Study of the Fermentation of Legume Silage. Pennsylvania State College, Graduate Thesis.

Moore, L. A. and R. Ely. 1941. Extraction of Carotene from Plant Material. Indus. and Engin. Chem., Analyt. Ed. 13: 600.

Newlander, J. A., H. B. Ellenberger and C. H. Jones. 1942. The Conservation of Nutrients in Grass Silage. IV Vt. Agr. Expt. Sta. Bul. 485.

Odland, T. E., T. R. Cox and J. B. Smith. 1941. A Comparison of Different Crops for Grass Silage by the Use of Mason Jars as Miniature Silos. Amer. Soc. Agron. Jour. 33: 304.

Snedecor, G. W. Statistical Methods. 4th Ed. The Iowa State College Press, Ames, Iowa.

Stone, R. W., S. I. Bechdel, H. D. McAuliffe, F. R. Murdock and R. C. Malzahn. 1943. The Fermentation of Alfalfa Silage. Penn. Agr. Expt. Sta. Bul. 444.

EFFECT OF RATION UPON SOME CONSTITUENTS OF BLOOD AND MILK OF HFREFORD COWS AND THE BLOOD OF THEIR CALVES

W. J. Van Arsdell, O. B. Ross and R. W. MacVicar
Oklahoma A. and M. College

EXTENSIVE studies of a commercial cow herd managed under range conditions reported by Ross *et al.* (1947, 1948, 1949) have suggested strongly that seasonally low levels of plasma carotene and vitamin A may be somewhat less serious than generally assumed. Average plasma levels of carotene and vitamin A as low as 57 and 10.9 mcg. per 100 ml. respectively, have been observed without serious effect upon either the cow or suckling calf. The lowest levels of these two constituents have occurred during March, when the dietary intake of carotene was minimal and the cows were lactating. During some years mild symptoms suggestive of vitamin A deficiency were observed. If a sub-clinical vitamin A deficiency did, indeed, exist, it was not of such severity as to affect the weaning weights of calves or general thrift of cows or calves.

In view of these observations, it was deemed desirable to initiate a study under more controlled conditions of the effect of level of carotene intake as supplied by alfalfa hay upon certain blood and milk constituents of Hereford cows and the resultant nutritional status and performance of their calves.

Experimental

This experiment was designed to study the carotene and vitamin A nutrition of cows and calves under controlled conditions comparable to those found on Oklahoma ranges. While it was necessary to confine the cows and calves for this experiment, an attempt was made to provide feed similar to that provided cows on the range (Ross, *et al.* 1947, 1948, 1949).

Nine bred grade Hereford cows averaging 6.5 years of age were selected for this study. They were grazed during the summer and fall of 1947 on native grasses supplemented only with a mineral mixture consisting of 3 parts salt and 1 part steamed bone meal. The cows were fed 3 pounds of cottonseed cake per head daily in addition to the dry grass from November 11 to December 20, at which time they were divided into 3 equal lots and placed in individual experimental pens. Following an adjustment period on a ration of prairie hay and cottonseed cake, the rations were changed on January 8, 1948, to those shown in table 1. The weathered prairie hay fed had been cut in December, 1947. Chemical examination showed that it contained less than 5 mcg. of beta carotene per gram. The principal species of

grass in the hay were: *Andropogon geraridi* (big bluestem), *Andropogon scoparius* (little bluestem), *Panicum virgatum* (switch grass), and *Sorghastrum nutans* (Indian grass). All cows were allowed free access to the salt-bone meal mineral mixture. The calculated average daily crude protein intake per cow was 1.25, 1.37, and 1.32 pounds for lots 1, 2, and 3, respectively. The rations were fed each cow until 30 days after the parturition date at which time she and her calf were removed from the experiment and returned to a native grass pasture. No records were maintained during the grazing period except the weaning weights of the calves.

Blood samples were collected from the cows by venous puncture at weekly intervals until time of parturition. The cows were bled at calving, daily for 10 days, and on the 20th and 30th days following parturition. The calves were bled at birth before they had nursed, every 4 hours for 24 hours, daily for 9 days and on the 20th and 30th days.

TABLE 1. RATIONS FED AND WEIGHT DATA

	Lot I	Lot II	Lot III
Weathered prairie hay (lbs.)	15.05	17.75	17.56
Alfalfa hay (lbs.)	5.0	2.5	—
Cottonseed cake (lbs.)	—	1.0	1.77
Av. wt. cows (lbs.)			
January 8, 1948	973	1055	985
Average days on ration	107*	86	77
Carotene intake mg/cow/day	106	75	38
Av. wt. calves (lbs.)			
Birth	69	71	67
28 days	117	121	106
Weaning	450	512	503
Av. age at weaning (days)	174	195	204
Av. daily gain (lbs.)			
1st 28 days	1.7	1.8	1.4
28 days to weaning	2.30	2.33	2.25

* One cow calved later than others; therefore she was fed the experimental ration for 181 days.

A sample of colostrum was collected before the calf had nursed and milk samples were taken daily for 4 days and on the 10th, 20th, and 30th day of lactation. Samples of milk were obtained by completely milking out one quarter of the udder. Blood and milk were refrigerated immediately after collection and analyzed as soon as possible. Plasma carotene and vitamin A analyses were made by the method of Kimble (1939). The milk was analyzed for carotene and vitamin A essentially as described by Boyer, *et al.* (1944).

Results and Discussion

The results of blood plasma and milk analyses are shown in tables 2, 3, and 4.

TABLE 2. BLOOD PLASMA ANALYSES—AVERAGE BY LOTS— COWS

Lot	Days prepartal				Partu-rition	Days postpartal											
	26	19	12	5		1	2	3	4	5	6	7	8	9	10	20	30
						Carotene (mcg per 100 ml)											
1	83	98	92	85	96	83	90	63	58	77	69	64	70	68	68	81	90
2	75	66	57	53	59	53	52	41	57	50	47	51	48	54	61	60	65
3	54	50	42	46	42	39	37	31	34	30	34	33	33	34	36	47	44
						Vitamin A (mcg per 100 ml)											
1	20.8	14.1	16.4	14.7	18.3	15.7	15.0	8.6	10.8	14.3	15.2	13.3	15.8	15.2	14.7	13.4	16.0
2	21.3	16.3	15.5	11.5	11.6	16.1	13.1	12.9	9.3	7.1	8.8	8.6	10.0	12.4	16.2	12.9	17.2
3	18.4	13.1	18.5	14.7	12.2	12.6	12.4	11.6	11.0	12.7	6.5	8.3	5.5	5.4	7.8	13.3	13.3

TABLE 3. BLOOD PLASMA ANALYSES—AVERAGE BY LOTS—CALVES

Lot	Age of calves—birth	Hours						Days										
		4	8	12	16	20	24	2	3	4	5	6	7	8	9	10	20	30
								Carotene (mcg per 100 ml)										
1	3.4	9.0	6.2	6.0	9.0	5.2	8.7	11.0	15.0	17.7	16.7	10.0	4.7	3.9	4.2	4.7	15.9	21.0
2	0.0	1.0	3.5	2.0	3.0	6.0	4.0	7.0	5.5	1.0	2.0	5.9	7.0	4.0	6.7	4.0	8.2	7.5
3	0.0	2.2	0.0	3.0	5.0	3.0	0.2	4.2	1.0	4.5	2.0	4.0	5.0	3.5	3.2	4.0	5.0	4.0
								Vitamin A (mcg per 100 ml)										
1	4.2	6.6	8.4	10.3	11.2	10.8	11.5	17.5	15.2	16.7	12.6	11.9	9.5	10.8	11.3	10.0	10.4	10.1
2	4.3	5.5	8.2	5.3	11.6	16.4	9.2	17.5	19.0	15.1	14.7	13.6	13.5	18.3	18.0	14.0	12.7	8.2
3	2.3	5.6	2.9	6.8	6.2	5.4	9.4	9.9	13.7	11.8	15.5	14.4	9.1	9.1	9.5	12.6	6.0	7.5

At no time did the average plasma level of carotene of the cows of Lot 1 that received a calculated daily carotene intake of 106 mg. fall below that of the cows of either Lots 2 or 3. The level fluctuated somewhat prior to parturition and on the 5th day before calving was 85 mcg. per 100 ml. of plasma. The level increased to 96 mcg. at time of parturition but decreased to 58 mcg. on the 4th day after parturition. The carotene had increased to 90 mcg. per 100 ml. of plasma on the 30th day after parturition.

Essentially the same trend was observed for the cows of Lot 2 that were fed 75 mg. of carotene daily. The average plasma carotene level increased

TABLE 4. MILK ANALYSES—AVERAGE BY LOTS

(mcg per 100 ml)

Days	Colostrum	1	2	3	4	10	20	30
				Carotene				
Lot 1	29.9	18.2	15.3	6.0	6.0	6.0	6.3	6.7
Lot 2	35.9	15.8	8.6	9.9	12.5	6.4	8.6	6.8
Lot 3	24.2	11.4	5.4	6.5	5.6	4.0	7.0	5.1
				Vitamin A				
Lot 1	114.2	63.5	41.6	18.7	15.3	10.7	7.0	4.4
Lot 2	37.3	35.4	18.8	8.4	25.2	9.4	14.6	13.3
Lot 3	96.8	54.2	37.5	26.6	19.3	9.8	10.0	8.4

slightly from the 5th day prior to parturition to the date of parturition, reached the lowest point during the study on the 3rd day following parturition and then increased slightly until the cows were turned to grass.

The plasma carotene level of the cows of Lot 3 fed 38 mg. of carotene daily was 54 mcg. per 100 ml. on the 26th day before calving. The level fluctuated slightly up to the 5th day before parturition and decreased to 42 mcg. at time of parturition. The lowest level was observed on the 3rd and 5th day following parturition. The plasma carotene levels of the cows of Lots 2 and 3 were considerably lower than the levels of Hereford cows reported by Payne and Kingman (1947). They reported, however, that aged Hereford cows with carotene plasma levels as low as 82.88 ± 4.11 mcg. per 100 ml. showed no symptoms which could be attributed to carotene deficiency. Gallup and Kuhlman (1941), Sutton and Soldner (1943), Kuhlman and Gallup (1944), and Sutton, Kaeser, and Soldner (1945) observed in dairy cattle a decrease in the plasma carotene during the last week of pregnancy. Two of the three lots of cows in this study failed to show this characteristic decrease in plasma carotene just prior to parturition, but the plasma carotene of all lots decreased immediately after calving in the same manner as the dairy cows studied by these authors.

The differences among the three lots in the level of plasma vitamin A was less marked than was the case for the plasma carotene. A consistent increase or decrease just prior to parturition was not observed nor was the immediate decrease following parturition as marked as the trend found for carotene. The lowest levels of plasma vitamin A for Lots 1, 2, and 3, respectively, were found on the 3rd, 5th, and 8th day following parturition. The levels for all three lots were considerably higher on the 13th day following parturition than for the days when the lowest levels were found.

Only 2 of the 9 calves had measurable amounts of plasma carotene at the initial bleeding. Both calves were from cows of Lot 1 fed the highest level of carotene. The levels of carotene in the plasma of all calves, irrespective of lots, increased from birth to 24 hours of age but the maximum levels were not reached until the 2nd to the 4th day of age. The plasma carotene level of the calves of Lot 1 decreased rapidly from the 5th to the 8th day of age but by the 13th day had increased to the highest level found during any of the bleeding dates. Aside from this rapid decrease beginning on the 5th day in the calves of Lot 1, the trends for all lots were essentially the same.

Low levels of plasma vitamin A were found in the calves of all lots at birth but the vitamin A increased rapidly during the first 24 hours. Highest levels of plasma vitamin A were observed in all lots on the 2nd to the 5th day of age. The vitamin A levels of the calves of all lots were lower at 30 days of age than during the peak levels observed during the first week. Wise *et al.* (1948) observed similar results with dairy calves.

The average colostrum carotene levels were found to be 29.9, 35.9, and 24.2 mcg. per 100 ml. for Lots 1, 2, and 3, respectively. The carotene level of the milk of the cows of Lots 1 and 3 dropped rapidly until the 2nd or 3rd day and then remained fairly constant for the next 26 days. One cow of Lot 2 was found to have more carotene and vitamin A in the milk on the 4th, 5th, and 6th days than in her colostrum. The increase in both milk carotene and vitamin A for the cows of Lot 2 on the 4th day was caused by this unusual occurrence.

The average colostrum vitamin A levels were found to be 114.2, 37.3, and 96.8 mcg. per 100 ml. for Lots 1, 2, and 3, respectively. The level of vitamin A in the milk of the cows of Lots 1 and 3 decreased rapidly the first 4 days and then stabilized at a fairly constant level for the remainder of the 30-day period. With the exception of one cow in Lot 2, the vitamin A level of the colostrum and milk of the cows of Lot 2 followed essentially the same pattern as the other two lots. Sutton, Warner, and Kaeser (1947) found a rapid decline of carotene and vitamin A in colostrum and milk with each successive milking, while studying dairy cattle, similar to that noted in this study. Levels closely approaching normal milk were reached at the end of the third day.

All of the calves of Lot 1 were strong and vigorous at birth. Two cows had temporarily retained placentas but required no assistance in eliminating them. Two of the calves of Lot 2 were strong and vigorous at birth. One calf appeared less vigorous at birth than the others and scoured from the sixth to tenth day of age at which time the condition stopped and the calf appeared normal thereafter. No evidence of retained placentas was observed. All of the calves of Lot 3 were weaker at birth than the calves of the other 2 lots. One calf had diarrhea most of the time during the first 28 days and a second calf scoured during the first week but stopped and was apparently normal at the time the cow and calf were turned to grass.

The symptoms of some of the calves of Lots 2 and 3 were suggestive of vitamin A deficiency but the relatively short duration of these symptoms apparently had no serious effect upon the calves as shown by the respective weaning weights of the calves (table 1). The cows likewise rebred without difficulty. The cows and calves had access to good pasture from 30 days post-partum to weaning age.

In general, these findings under conditions of controlled carotene intake confirm the results of field investigations. The cows were able to produce normal calves and suckle them for a thirty day period without ill effects even though the blood carotene and vitamin A values were within the range considered to signify a sub-optimal supply of this nutrient. No obvious correlation was noted between the concentration of carotene or vitamin A in colostrum or milk and the intake of carotene. It should be emphasized, however, that these animals had received an ample carotene supply during the preceding summer and early fall and doubtless entered the experimental period with ample stores of carotene and vitamin A. If the cows had been under conditions of carotene deprivation during the preceding summer or if they had been forced to subsist on the lower intake for the entire nursing period, clinical symptoms of vitamin A deficiency might have become apparent. Since these conditions occur on the ranges of the Southwest only during periods of severe drought, it would appear that the low blood carotene and vitamin A levels frequently observed during late winter are not indicative of a serious deficiency state.

Summary

1. The effect of three different levels of carotene intake, supplied by alfalfa hay, upon the carotene and vitamin A concentration of the blood and milk of Hereford cows and the blood of their calves is reported.

2. Plasma carotene levels were positively correlated with carotene intake. No consistent differences in plasma vitamin A could be attributed to ration. Both plasma carotene and vitamin A declined at or shortly after parturition

and then rose during the subsequent 30 days. The plasma carotene and vitamin A level of the calves increased rapidly during the first few days and then decreased to a level which was generally maintained throughout the first month of life.

3. Despite the relatively low blood plasma levels of carotene and vitamin A observed during this study all the cows produced normal calves and raised them successfully. It is suggested that seasonal declines of plasma vitamin A and carotene may occur for short periods of time without the appearance of clinical symptoms of avitaminosis.

Literature Cited

Boyer, P. D., R. Spitzer, C. W. Jensen and P. H. Phillips. 1944. Determination of Vitamin A and Carotene in Milk. Ind. and Eng. Chem. Anal. Ed. 10: 101.

Gallup, W. D. and A. H. Kuhlman. 1941. Carotene Content of the Blood Plasma of Dairy Cattle in Relation to Vitamin A Deficiency. Proc. Okla. Acad. Sci. 21: 89.

Kimble, M. S. 1939. Photocolorimetric Determination of Vitamin A and Carotene in Human Plasma. Jour. Lab. Clin. Med. 24: 1055.

Kuhlman, A. H. and W. D. Gallup. 1941. Carotene Requirements of Dairy Cattle for Lactation. Jour. Dairy Sci. 24: 522.

Kuhlman, A. H. and W. D. Gallup. 1944. Changes in Blood Plasma Carotene Associated with Parturition and Lactation of Jersey Cows. Jour. Dairy Sci. 27: 633.

Payne, M. G. and H. E. Kingman. 1947. Carotene Blood Levels and Reproductive Performance in Range Hereford Cattle. JOURNAL OF ANIMAL SCIENCE, 6: 50.

Ross, O. B., D. F. Stephens, A. E. Darlow, W. D. Campbell, J. C. Hillier and V. G. Heller. 1947. The Utilization of Bluestem Grass in Maintaining the Commercial Cow Herd. Okla. Agr. Exp. Sta. MP-11: 5.

Ross, O. B., R. W. MacVicar, D. F. Stephens, W. J. Van Arsdell, W. D. Campbell, and A. E. Darlow. 1948. Methods of Wintering Commercial Cows. Okla. Agr. Exp. Sta. MP-13: 5.

Ross, O. B., R. W. MacVicar, D. F. Stephens, W. J. Van Arsdell, W. D. Campbell and A. E. Darlow. 1949. Methods of Management and Protein Supplements for a Commercial Cow Herd. Okla. Agr. Exp. Sta. MP-15: 38.

Sutton, T. S. and P. A. Soldner, 1943. The Effect of Parturition and Beginning Lactation on the Level of Carotene and Vitamin A in the Blood Plasma of Dairy Cows. Jour. Dairy Sci. 26: 8.

Sutton, T. S., H. E. Kaeser and P. A. Soldner. 1945. Changes in the Level of Vitamin A and Carotene in the Blood Plasma of Dairy Cows Associated with Parturition and Beginning Lactation. Jour. Dairy Sci. 28: 933.

Sutton, T. S., R. G. Warner and H. E. Kaeser. 1947. The Concentration and Output of Carotenoid Pigments, Vitamin A and Riboflavin in the Colostrum and Milk of Dairy Cows. Jour. Dairy Sci. 30: 12.

Wise, G. H., M. J. Caldwell, D. B. Parrish, F. W. Atkeson and J. S. Hughes. 1948. Relation of Typical Postnatal Changes in the Diet of the Dairy Calf to the Concentration of Carotenoids and Vitamin A in the Blood Serum. JOURNAL OF ANIMAL SCIENCE. 7: 70.

DEPOSITION AND ALIMENTARY EXCRETION OF PHOSPHORUS-32 IN STEERS ON HIGH MOLYBDENUM AND COPPER DIETS[1]

RAY L. SHIRLEY, RILEY DEAL OWENS AND GEORGE K. DAVIS
University of Florida Agricultural Experiment Station

RADIOACTIVE phosphorus-32 when used as a "tag" makes possible a means of following the deposition and excretion of phosphorus and of observing the influence of different dietary states upon these processes. Comar, Singer, and Davis (1949) have observed an interrelationship between copper, molybdenum and phosphorus in rats, using radioactive isotopes to demonstrate the influence of high concentrations of each in the diet on the absorption and distribution of the others by the body. Shirley, Owens and Davis (1950) have shown that rats on high molybdenum and copper diets vary considerably in their excretion of radioactive phosphorus in the feces and urine after intramuscular administration. The purpose of this investigation was to study (a) the influence of high levels of molybdenum and copper on the deposition of phosphorus in the various tissues of cattle, and (b) the function of each segment of the alimentary tract of cattle in the excretion of phosphorus.

Experimental Procedure

In this investigation four Jersey steers, approximately three years of age on an adequate corn, cottonseed meal and hay ration in a dry lot, were drenched daily for a period of seven months with an aqueous solution containing levels of copper sulfate and sodium molybdate of 5.0 and 3.1, 5.0 and 0, 0 and 3.1, and 0 and 0 grams per day, respectively. The molybdenum concentration was estimated as being about 200 parts per million in the ration. After about 14 weeks of drenching, a second steer on the high copper level died with symptoms of acute copper poisoning (Henson, 1949). However, none of the steers used in this tracer experiment showed any marked symptoms of toxicity from either the high levels of copper or molybdenum. At the time of sacrifice, these steers weighed 675, 740, 600 and 650 pounds, respectively.

Each steer was injected intramuscularly in the right shoulder with 2 ml. of an aqueous solution which contained approximately 500 microcuries of carrier-free radioactive phosphorus[2] in the form of phosphoric acid. The feces

[1] Published with the permission of the Director of the Florida Agricultural Experiment Station. This investigation was supported in part by grants from the Nutrition Foundation, Inc., New York, and from the U. S. Phosphoric Company, Division of Tennessee Corporation.

[2] The phosphorus-32 was obtained from the Oak Ridge National Laboratory, Oak Ridge, Tennessee, after authorization by the Atomic Energy Commission Isotopes Division.

and urine were collected and the steers were sacrificed 40 hours after administration of the isotope. Representative samples of the principal organs were secured in addition to samples of the mucosa, muscularis, and contents of the various segments of the alimentary tract. These samples were decomposed by wet digestion with nitric acid, diluted to volume in volumetric flasks and aliquots were taken for radioactivity measurements and total phosphorus determinations. The activity assays were made using immersion-type Geiger-Mueller tubes and the total phosphorus was determined by the colorimetric phosphomolybdate method (Fiske and Subbarow, 1925).

Results and Discussion

Tissue Distribution

In table 1 the values are given that were obtained for the percent dose of injected radioactive phosphorus per unit of weight (or volume) and percent dose per 100 milligrams of total phosphorus present in the organs and non-alimentary tissues of the four steers. The isotope distributions in the non-alimentary tissues of the steers on the four different treatments were very similar, although the steer receiving added copper and molybdenum had somewhat less phosphorus-32 in the various tissues. The total amount of

TABLE 1. DEPOSITION OF PHOSPHORUS-32 IN THE TISSUES

Tissue	Steer No. 1 High Mo and high Cu		Steer No. 2 High Cu		Steer No. 3 High Mo		Steer No. 4 Basal	
	% dose per 100 g. tissue	% dose per 100 g. P	% dose per 100 g. tissue	% dose per 100 g. P	% dose per 100 g. tissue	% dose per 100 g. P	% dose per 100 g. tissue	% dose per 100 g. P
Femur	0.03	0.0002	0.05	0.0003	0.05	0.0004	0.05	0.0005
Ribs	0.05	0.0004	0.11	0.0013	0.09	0.0012	0.07	0.0008
Whole Blood*	0.02	0.02	0.04	0.05	0.08	0.05	0.08	0.03
Washed Blood Cells	0	0	0.003	0.04	0.007	0.04	0.003	0.02
Bile*	—	—	0.24	0.28	0.17	0.08	0.21	0.08
Gall Bladder	0.01	0.01	0.01	0.09	0.01	0.05	0.02	0.05
Brain	0.002	0.001	0.005	0.002	0.003	0.001	0.004	0.002
Heart	0.05	0.03	0.06	0.04	0.05	0.03	0.07	0.05
Kidney	0.07	0.05	0.09	0.05	0.10	0.04	0.08	0.04
Liver	0.10	0.02	0.15	0.05	0.12	0.05	0.14	0.05
Lungs	0.03	0.01	0.04	0.03	0.05	0.03	0.03	0.02
Pancreas	0.04	0.01	0.06	0.02	0.07	0.23	0.07	0.03
Spleen	0.04	0.02	0.06	0.02	0.05	0.02	0.06	0.01
Salivary	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.04
Parotid	0.04	0.02	0.06	0.03	0.07	0.03	0.05	0.03
Adrenals	0.04	0.01	0.05	0.02	0.05	0.02	0.07	0.03
Hide	0.01	0.02	0.01	0.05	0.01	0.03	0.01	0.01

* Values for percent dose are reported as percent dose per 100 grams of sample, except in the case of the whole blood and the bile, which are reported on the basis of percent dose found present per liter. No bile was found in the gall bladder of Steer No. 1. No radioactivity was detected in the washed blood cells of Steer No. 1, or in the hair of any of the steers.

labeled phosphorus deposited in the bone was large compared to that in the other tissues, but when calculated to terms of per 100 grams of tissue, the concentration of isotope in the heart, kidney, lung, pancreas, spleen, salivary, parotid and adrenal glands was equivalent to that in the ribs and femur. While the bones serve as a reservoir of phosphorus, the distribution of labeled phosphorus 40 hours after injection indicates a turnover or rate of exchange between circulating phosphorus and the tissues listed that is quite comparable to the rate of exchange between circulating phosphorus and the bones.

Of the tissues examined, the liver contained more isotope per 100 grams of tissue than any other organ, while the brain contained very little isotope. The low concentration of radioactive phosphorus in the brain probably is a reflection of the slow turnover and in the period between injection and slaughter very little replacement of phosphorus with phosphorus-32 had occurred in the brain.

When the concentration of phosphorus-32 in the tissues was calculated on a basis of percent dose per 100 milligrams of total phosphorus, the bones and the brain were found to be much lower than the other body tissues. The low value for the bone reflects the large amount of phosphorus already present in the bone. Cohn and Greenberg (1938) noted that injected phosphorus was found to a greater extent in bone and liver of the rat, with less in the brain than in the other body tissues. The values found with the cattle in these studies are in good agreement.

Alimentary Tract Distribution

In figures 1 and 2, data are presented graphically that were obtained for the percent dose and percent dose per 100 milligrams of total phosphorus of injected isotope in the alimentary tissues and contents of the four steers.

With some slight variation, the percent dose of phosphorus per 100 milligrams of total phosphorus showed a remarkable uniformity throughout the alimentary tract. This is especially noteworthy in view of the variation in values for the contents and for the feces. The large size of the rumen and reticulum resulted in the contents of these organs containing a large proportion of the injected phosphorus-32. When reduced to a basis of 100 milligrams of total phosphorus, the values for the rumen-reticulum contents were similar to those found in the contents of the other tissues.

It will be observed in both figure 1 and figure 2 that the effect of added copper and added molybdenum is exhibited where added individually by increased phosphorus-32 values in the alimentary contents. This is particularly demonstrated in figure 2, when the percent dose values are calculated to a total phosphorus basis. The higher values observed with the high

molybdenum treatment were further reflected in the values for the feces collected over the period between injection of the labeled phosphorus and slaughter.

The high value found in the rectum contents of the steer receiving added copper was associated with a small weight of contents, reflecting relatively recent defecation. It is possible that the value was due to a change in the excretory pathway, but in view of the level of isotope in the feces, it seems

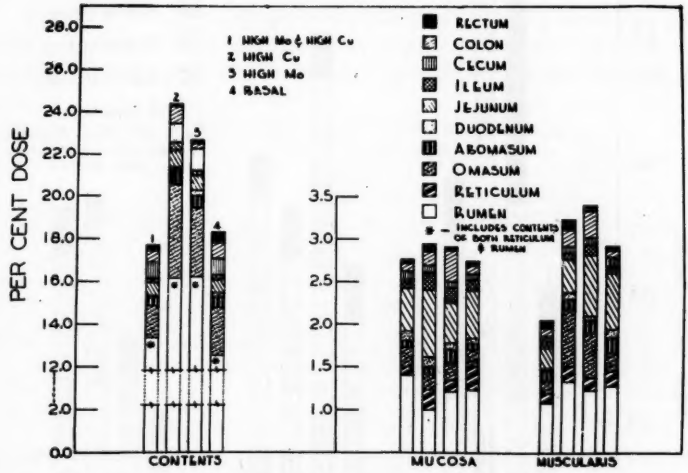

Figure 1. Percent dose of phosphorus-32 found in the contents, mucosa, and muscularis of the various alimentary segments.

more likely that there was less natural mixing of the rectum contents with the residual contents containing much of the excreted isotope.

Although the labeled phosphorus in the tissues of the intestinal tract appeared to be rather uniform, especially on the basis of 100 milligrams of total phosphorus present, the influence of the various supplements, added copper and molybdenum, added molybdenum, and added copper, as shown by the phosphorus-32 in alimentary contents and feces, emphasizes the influence of these metallic elements upon the phosphorus excretion.

The use of copper salts as a means of counteracting the presence of high levels of molybdenum has become an accepted practice in many areas of this country and others. The balancing influence of these elements is shown by the fact that values obtained for phosphorus-32 distribution with the animal receiving the basal ration plus added copper and molybdenum were similar

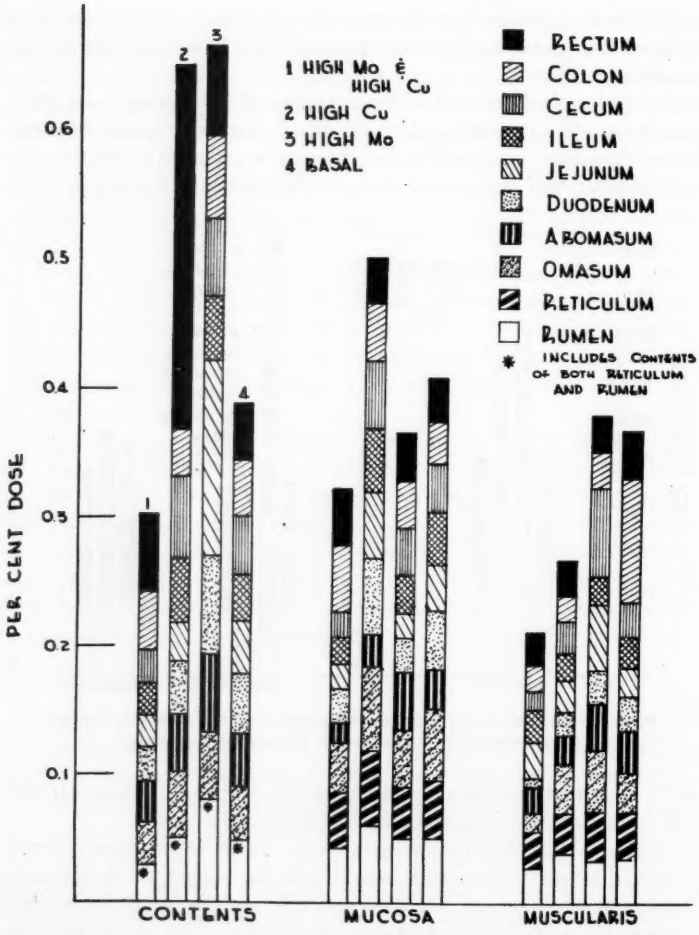

Figure 2. Percent dose of phosphorus-32 per 100 milligrams of total phosphorus found in the contents, mucosa and muscularis of the various alimentary segments.

in practically all instances to the values obtained with the animal receiving the basal ration.

When supplements of copper or molybdenum salts were administered alone, as compared to their administration together or their lack of adminis-

tration, there was a change in the phosphorus metabolism. Special attention is drawn to the effect of added molybdenum, which appeared to change not only the pathway of excretion, but also the rate of excretion, as exhibited by the high phosphorus content of the feces, and the very low content of the urine, as compared to the control or to the animals receiving supplemental copper and molybdenum.

Feces and Urine Values

In table 2, the percent of dose of phosphorus-32 and the percent dose per 100 milligrams of total phosphorus are given for the feces and urine, as excreted by the steers on the different treatments. Particular attention is

TABLE 2. EXCRETION OF PHOSPHORUS

Steer No.	Treatment	Feces			Urine		
		% Dose	% dose per 100 mg.	Total P mg.	% Dose	% dose per 100 mg.	Total P mg.
1	High Mo High Cu	2.32	0.05	4680.0	0.14	0.02	542.0
2	High Cu	1.97	0.04	4700.0	0.07	0.18	36.0
3	High Mo	9.44	0.06	15,600.0	0.04	0.14	28.0
4	Basal	0.57	0.01	5160.0	2.48	0.11	2300.0

drawn to the change in the route of excretion, which occurred when the steer was given added molybdenum. The feces contained more than three times the total phosphorus found in the feces of the other steers, whereas the urine was particularly low in total phosphorus. The urine of the animal receiving added copper was also very low.

The change in excretory route under the influence of the added copper and molybdenum is even more striking where the percent dose values for urine and feces are observed. Under the influence of the added molybdenum, added copper and added molybdenum and copper supplements. the excretory ratio of the basal ration was strikingly reversed. The feces to urine ratio varied from 0.57 to 2.48 with the basal ration to 9.44 to 0.04 with added molybdenum, in terms of percent dose of labeled phosphorus excreted.

These results would appear to confirm findings observed in the field and in other experimental work in which the presence of molybdenum in the diet has resulted in fragile bones, apparently due to an inability to maintain bone phosphorus levels.

The influence of copper on phosphorus metabolism would appear to be

less marked than that of molybdenum in that the excretory rate was not increased. However, there was a marked effect upon the excretory pathway and in reducing the effect of molybdenum.

The marked changes in phosphorus excretion noted in the steers have not been observed to the same degree when rats fed added molybdenum and copper supplements were injected with phosphorus-32 (Shirley, Owens and Davis, 1950). In the rat, two to three percent of the injected labeled phosphorus was found in the alimentary tissues and contents, which compared with that found in the steers, but the percent dose per 100 milligrams of total phosphorus was approximately 0.2 that in the steers. While this latter value reflects to some degree the larger amount of phosphorus in the tract of the steers, it also agrees with our observations that rats are much more tolerant of added molybdenum and copper than are cattle.

Summary

Jersey steers on high and low levels of molybdenum and copper were studied in regard to their capacity to deposit radioactive phosphorus, injected intramuscularly, in the principal tissues and organs of the body, as well as the distribution of the isotope in the contents of the various alimentary segments and in the feces and urine. The results were calculated as percent dose in the sample and as percent dose per 100 milligrams of total phosphorus present.

The steers were slaughtered 40 hours after the administration of the isotope and values were obtained for the liver, heart, kidney, lung, pancreas, spleen, salivary, parotid and adrenal glands, brain, rib and femur, as well as for the blood and alimentary tissues and contents.

The sodium molybdate supplement and the copper sulfate supplement markedly changed the pathway of phosphorus excretion from the partition usually found in cattle to one in which most of the phosphorus was excreted in the feces. The rate of phosphorus excretion was markedly increased when the molybdate supplement was given alone.

Copper sulfate and sodium molybdate supplements given together resulted in less effect upon the pathway of phosphorus excretion than when given individually, but did result in slightly lower tissue phosphorus values than those found in the other animals.

Acknowledgements

The authors wish to thank Mr. Alan M. Lovelace for making the phosphorus determinations used in this investigation.

Literature Cited

Cohn, W. E. and D. M. Greenberg. 1938. Studies in Mineral Metabolism and Aid of Artificial Radioactive Isotopes. I. Absorption, Distribution, and Excretion of Phosphorus. Jour. Biol. Chem. 123: 185.

Comar, C. L., Leon Singer and George K. Davis. 1949. Molybdenum Metabolism and Interrelationships with Copper and Phosphorus. Jour. Biol. Chem. 180: 913.

Fiske, C. H. and Y. Subbarow. 1925. The Colorimetric Determination of Phosphorus. Jour. Biol. Chem. 66: 375.

Henson, Jr., Jesse N. 1949. Interrelationships of Copper and Molybdenum Upon Phosphorus Metabolism and Alkaline Blood Phosphatase Levels in Cattle. A thesis transmitted to the Graduate Council in partial fulfillment of the requirements of the Master of Science in Agriculture degree, University of Florida, September, 1949.

Shirley, Ray L., Riley Deal Owens and George K. Davis. 1950. Excretion of Radioactive Phosphorus into the Alimentary Tract of Rats on High Molybdenum and Copper Diets. Unpublished data.

THE INFLUENCE OF SOLVENT EXTRACTED AND HYDRAULIC PROCESSED COTTONSEED MEALS UPON PERFORMANCE AND LEVEL OF PLASMA CAROTENE, VITAMIN A, AND FAT IN THE BLOOD OF WINTERING BEEF COWS

A. P. Parham, R. W. Colby and J. K. Riggs
Texas Agricultural Experiment Station[1]

THE practice of hand feeding a limited amount of protein concentrate to beef breeding cattle during the winter period has long been followed in range areas of the United States. With increased use of solvent extracted plant protein supplements and the consequent lowering of fat content of the ration of range cattle, the question of relation between lowered fat content of the ration and absorption of carotene from the gut now presents a problem. Since carotene is frequently a critical vitamin for range animals, any feed or feeding practice which would interfere with maximum utilization of this vitamin is to be avoided.

Maynard *et al.* (1929, 1932 and 1934) have demonstrated the importance of the fat component in the ration of dairy cattle. They have shown that removal of most of the fat from the ration by solvent extraction results in a marked lowering of milk yield despite isodynamic replacement of the fat by carbohydrate.

Mendel (1930) found that an abundance of fat in rations led to a decidedly larger storage of fats than did an equicaloric intake of carbohydrate. Ellis and Zeller (1930) report, however, that a hog ration containing only 0.15 percent fat resulted in fat storage at a normal rate and the attainment of a normal degree of fatness.

Bender and Maynard (1932) working with lactating goats found that the level of blood lipids showed marked variations which in general followed changes in fat intake. The parallelism between the various lipids with the changes in total lipids was observed in this as in previous studies.

Williams and Maynard (1934) found that in the plasma of lactating goats fed a diet of extremely low fat content, the total lipids, phospholipids, and total and free cholesterol decreased gradually, and increased when fat was added to the diet.

Raper (1950) in work with beef calves found that when the fat content of the ration was raised from two to five and one half percent, the plasma carotene level rose significantly. Plasma Vitamin A, liver Vitamin A and

[1] Departments of Animal Husbandry and Biochemistry and Nutrition, Texas Agricultural Experiment Station, Texas Agricultural and Mechanical College System, College Station, Texas.

carotene were not affected. Since the aforementioned workers have demonstrated the importance of fat in rations for farm animals, it was decided to test the effect of solvent versus hydraulic processed cottonseed meals under conditions which simulate those followed under actual range conditions.

The work reported herein was undertaken to determine (1) the feed utility of 41% protein solvent-extracted cottonseed meal, containing 1.0% ether extract, in comparison to 41% protein hydraulic-processed cottonseed meal, containing 5.0% ether extract; and (2) to study the influence of the feeding of these two types of meals on the plasma carotene and vitamin A levels and on the blood fat levels of wintering beef breeding cows.

Experimental Procedure

Thirty-eight head of purebred beef cows of Hereford and Aberdeen-Angus breeding, were divided into two groups of nineteen as nearly alike with respect to age, breed, and expected date of parturition, as possible. They were wintered on improved Brazos County upland pasture in which Bermuda grass was the principal species of forage in the early part of the wintering period with bur clover and rescue grass forming a larger percentage of the total toward the latter part of the period. In addition to the permanent pasture, the cows had access to fall sown oats from January 1, 1950, until the end of the trial. One group was hand fed two pounds per head per day of 41% protein cottonseed meal[2] made by solvent extraction process. The other group was fed the same amount of 41% protein cottonseed meal made by the hydraulic process. The feeding period began on December 1, 1949, and continued for 112 days, or until sufficient grazing was available to make supplemental feeding no longer necessary. Sumac silage was fed in like amounts to both groups since the pasture forage was not adequate to maintain the cattle. The two groups were alternated on the two pastures every two weeks in order to equalize the effect of pastures.

Blood samples were taken from the entire 38 head before they were placed on feed. Plasma carotene, vitamin A (method of Kimble, 1939) and fat (method of Allen, 1934) were determined from these samples. Ten blood samples were taken at random from each group every 28 days and were analyzed as stated above. At the end of the winter feeding period, which was March 21, 1950, duplicate blood samples were taken from the entire 38 head and analyzed as before. Individual weights were taken before the cows were placed on feed and also every 28 days at the time the blood samples were drawn.

Complete records of feed consumption were also kept.

[2] The hydraulic and solvent extracted cottonseed meals used in this study were made available through the courtesy of the Buckeye Cotton Oil Company—Cincinnati, Ohio.

Results and Discussion

Both groups of cattle consumed an average of 2 pounds of cottonseed meal plus 34 pounds of sumac silage per head daily. It was estimated that forage consumed from pasture amounted to 30 pounds per head daily. Ether extract analysis of the feeds indicated an intake of 0.5 pound of fat by the cattle receiving solvent extracted cottonseed meal and 0.6 pound for those receiving hydraulic processed cottonseed meal.

The data from this trial are summarized in table 1. The cows maintained their weight and even showed a slight gain during the wintering period. Those fed the hydraulic processed cottonseed meal gained 11 pounds more than those fed solvent extracted meal, but this difference is far too small to be statistically significant.

TABLE 1. WEIGHT, BLOOD FAT, CAROTENE AND VITAMIN A LEVELS OF BEEF BREEDING COWS WINTERED ON HYDRAULIC PROCESSED AND SOLVENT EXTRACTED COTTONSEED MEALS

Type of cottonseed meal	Hydraulic	Solvent
Number of cows	19	19
Number of days on trial	112	112
Av. initial weight, lbs.	1117	1139
Av. gain, lbs.	20	9
Av. initial fat content of blood, mg/100 ml.	176.3	178.6
Av. final fat content of blood, mg/100 ml.	187.5	176.6
Av. initial carotene content of blood, μg/100 ml.	130	166
Av. final carotene content of blood, μg/100 ml.	126	146
Av. initial vitamin A content of blood, μg/100 ml.	32	32
Av. final vitamin A content of blood, μg/100 ml.	106	126

The values for blood fat indicate that both groups of animals had similar blood fat levels at the beginning of the experiment. This value averaged 177.5 mg. per 100 ml. of blood. During the course of the trial, the blood fat level of the cattle fed hydraulic processed meal rose 11.2 mg. per 100 ml. of blood. On the other hand, the level of blood fat for the cattle fed solvent extracted meal declined 2 mg. per 100 ml. of blood. The difference in average final blood fat was 10.9 mg. per 100 ml. and was statistically significant at the 5 percent level as shown by analysis of variance ($F = 4.89$). There was no significant difference in blood fat between breeds within groups.

The initial plasma carotene levels of the two groups of animals showed a difference of 36 μg. per 100 ml. of plasma in favor of the cows fed solvent extracted cottonseed meal and averaged 148 μg. per 100 ml. At the close of the experiment, these levels of carotene had declined 20 μg. per 100 ml. of plasma in the cows fed solvent extracted meal, but only 4 μg. in those fed

hydraulic processed meal. Because of the variation within groups, these differences were not statistically significant when analyzed by the method of variance.

Blood vitamin A levels were identical for the two groups of cattle at the beginning of the experiment, averaging 32 μg. per 100 ml. of plasma. For some unexplained reason, the vitamin A levels increased markedly during the first month of the trial, then remained fairly constant during the remainder of the test with an average final value of 116 μg. per 100 ml. No such changes took place in plasma carotene levels. The final blood vitamin A levels showed a difference of 20 μg. per 100 ml. of plasma in favor of the solvent meal group and this difference was not statistically significant.

The levels of carotene and vitamin A in the plasma are high due largely to the fact that the cows were wintered well on silage of good quality in addition to unusually good winter pasture where considerable green forage prevailed.

The results of this test indicate that feeding solvent extracted cottonseed meal to cattle at the levels used had little effect upon the levels of carotene and vitamin A in their blood. The significant depression in level of blood fat caused by feeding this meal was apparently not great enough to cause any untoward effects in the cattle. The amount of fat supplied by two pounds of cottonseed meal was apparently too small to influence carotene absorption.

Summary

Beef breeding cows fed hydraulic processed cottonseed meal showed a significantly higher level of blood fat at the close of a 112-day test than cows fed solvent extracted meal.

Blood fat levels for 19 cows fed hydraulic processed meal averaged 187 5 mg. per 100 ml. of blood at the close of the wintering period. The average for 19 cows fed solvent extracted meal was 176.6 mg.

Although the difference in levels of blood fat was statistically significant, this difference appeared to have little relationship to levels of carotene and vitamin A in the blood within the range which existed in this study.

Literature Cited

Allen, N. W. 1934. A Simple Volumetric Method for Determination of Fat in Blood Plasma. Proc. Soc. Exp. Biol. Med. 31: 991.

Bender, R. C. and L. A. Maynard, 1932. Fat Metabolism in the Lactating Goat. Jour. Dairy Sci. 15: 242.

Ellis, N. R. and J. H. Zeller, 1930. The Influence of a Ration Low in Fat upon the Composition of the Body Fat of Hogs. Jour. Biol. Chem. 89: 185.

Kimble, M. S., 1939. The Photocolorimetric Determination of Vitamin A and Carotene in Human Plasma. Jour. of Lab. and Clin. Med., 24: 1055.

Maynard, L. A. and C. M. McCay, 1929. The Influence of a Low-Fat Diet upon Fat Metabolism during Lactation. Jour. Nutr. 2: 67.

———, 1932. The Influence of Different Levels of Fat Intake upon Milk Secretion. Cornell Univ. Agr. Exp. Sta. Bul. 543: 1–40.

———, H. H. Williams and L. L. Madsen, 1934. II. Further Studies of the Influence of Different Levels of Fat Intake upon Milk Secretion. Cornell Univ. Agr. Expt. Sta. Bul., 593: 1–14.

Mendel, L. B., 1930. Some Relations of Diet to Fat Deposition in the Body. Yale Jour. Biol. Med. 3: 107.

Raper, J. T., 1950. The Effects of Two Levels of Fat in the Ration of Beef Cattle on the Absorption and Conversion of Beta Carotene to Vitamin A. M. S. Thesis, A. & M. College of Texas.

Williams, H. H. and L. A. Maynard, 1934. The Effect of Specific Dietary Fats on the Blood Lipids of Lactating Goats. Jour. Dairy Sci., 17: 223.

SIMPLIFIED METHODS AND EQUIPMENT USED IN SEPARATION OF URINE FROM FECES ELIMINATED BY HEIFERS AND BY STEERS

C. S. Hobbs, Sam L. Hansard and E. R. Barrick[1]
University of Tennessee

THERE is little information available on methods of separating the urine and feces in balance trials with mature cows and heifers. Forbes *et al.* (1937) and Briggs and Gallup (1949) reviewed the earlier literature and described acceptable methods for use with steers, involving adaptable commercial separators.

The complicated and expensive facilities required for balance trials with steers and heifers have heretofore limited the use of these animals in metabolism experimentation. This paper described an economical and dependable method for holding steers and heifers and simplified equipment that is adequate for the complete separation of the urine and feces eliminated by these experimental animals during short or extended balance studies.

Metabolism Unit

The details of the metabolism stall and adjustable feed box with stanchion feces container and splatter shield are shown in figure 1. This unit may be adaptable to either heifers or steers. The adjustable box is placed inside one end of the stall and is secured to each side by means of a 4-in. clamp. The feces collection box is made of No. 20 sheet metal. A shield is placed around 3 sides of the box to localize any splattering of feces. A 5-gal. carboy is located by the side of the feces box for the collection of urine from heifers and underneath the stand for collection of urine froom steers. Ferrox[2]—one or more coats—is applied to the cleaned floor area under the animal's feet to prevent slipping.

Method of Collecting Urine From Heifers

The urine conduit for heifers is constructed out of a 3-in. seamless rubber tube,[3] approximately 4 ft. long (figures 2 and 3). It is prepared for use as indicated in figure 2, by making a $3\frac{1}{2}$–5-in. incision along one side of the folded edge of one end of the tube and the terminal point of the incision is reinforced with a cold rubber patch (figure 2A-B). Wire rings attached, by cold rubber patches, to the outside of the upper portion of the tube have been found helpful in holding the tube open to permit a free flow

[1] E. R. Barrick now University of North Carolina, Raleigh, N.C.
[2] Ferrox, an abrasive paint—available from Am. Abrasive Metal Co., Irvington, N. J.
[3] "Gooch" tubing available from B. F. Goodrich Rubber Company, Akron, Ohio.

of urine (figure 2B). A thin piece of strap iron about 1 in. wide and 8 in. long, attached along the top outside end of the rubber tube by means of small screw clamps (figure 2D), may be bent inward near the center to assist in keeping the tube in position between the anus and vulva.

The split end of this conduit is placed around the vulva and secured to the heifer by means of 3 pairs of 2-in. webbing straps 10–12 in. in length

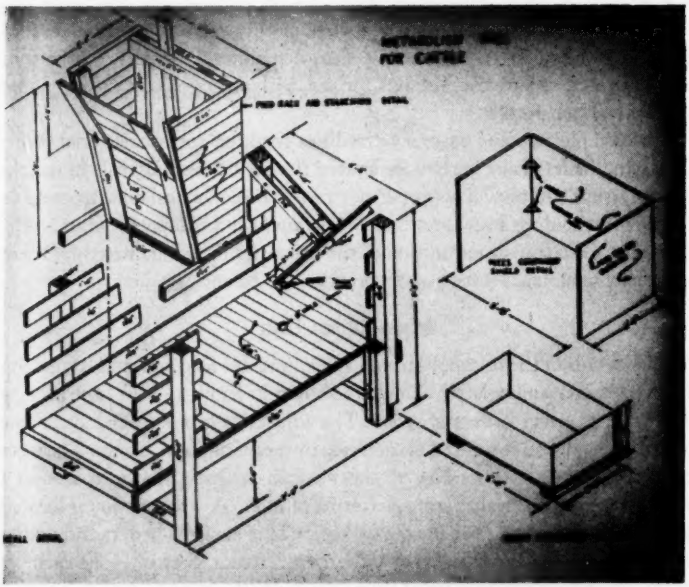

Figure 1. The metabolism unit, showing details of the stall, adjustable feedbox, feces container and shield.

(figure 2E). These straps are attached to the rubber conduit by means of open-sided clamps and to the cow's rump by means of branding cement.[4] The top pair of webbing straps (figure 2E) give vertical support to the tube and run from a point just above the pin bones to a point midway between the hip bones and the center of the rump. The lower pair of straps (figure 2E) serve to stretch the rubber to each side and extend from a point just below the pin bones to a point 4–6 in. below the hips. The additional 10-in. straps (figure 2E) are attached below just the vulva to hold the lower side of the tube in position. Final adjustments are made to prevent any contamination of the urine with fecal material by cementing the rubber conduit

[4] Branding cement obtained from the Nebraska Salesbook Co., P. O. Box 548, Lincoln, Neb.

to the section of skin between the anus and vulva (figure 3). This requires thorough preparatory cleansing with ether to remove the oily secretions. The

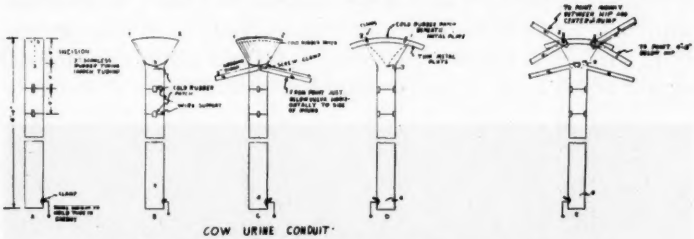

Figure 2. The cow urine conduit showing details of construction, assimilation and attachments.

Figure 3 The heifer urine conduit in position demonstrating attachments.

conduit is given additional support by means of a small cord attached to the side of the stand at the level of the heifer's back. The bottom of the tube is held in the carboy by a small weight sufficient to cause it to slide back when it is shifted by the animal's movements (figure 4). A 2 in. × 6 in. board 4 ft. long is hinged at the bottom to the back side of the stand and secured at top by an adjustable board arrangement (figure 4). It can be

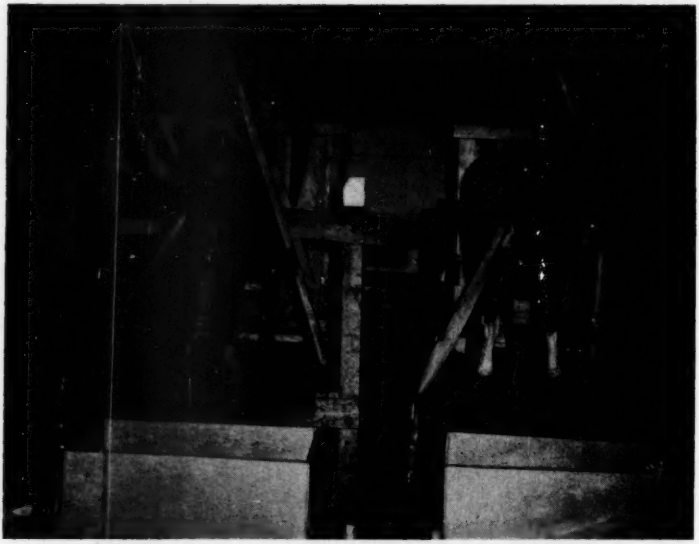

Figure 4. Two metabolism units with heifers in the stalls, illustrating the functioning of the unit as described.

adjusted to prevent excess lateral movement of the rear end of the animal. The heifer's tail is prevented from interfering with the clamps which attach the conduit to the supporting straps by means of a light weight at the end of a string that is tied to the switch and passed through a small suspended pulley (figure 4).

This procedure has worked satisfactorily during the past two years for collection periods of 14 days. The method of attaching the urine conduit has caused little inconvenience or discomfort to the heifer. The straps may be removed at any time with a fat solvent.

Method of Collecting Urine from Steers

A simple and satisfactory funnel for the collection of urine from steers is constructed as illustrated in figure 5. A ring of desired diameter is made

from steel wire, covered with rubber tubing, and the ends of the ring are braised or taped together (figure 5A). The necessary circumference is calculated and the body of the funnel is then measured and cut from thin rubber sheeting in two or three identical pieces. Sufficient overlap is desirable for gluing the sides together. A 3-inch opening is allowed at the bottom for the attachment of a seamless rubber tube neck for conducting the urine to a 5-gal. carboy beneath the stand. The body of the funnel is then pulled through and the sides turned down over the wire ring and firmly secured to the outside with rubber glue. To support this funnel in position beneath

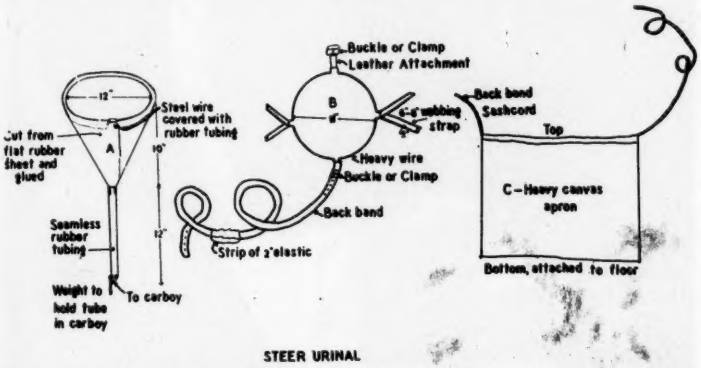

Figure 5. The steer urinal, showing funnel construction and supporting attachments for securing urinal in position. The protective canvas apron protects the urinal from the animal's rear feet.

the steer, another heavy wire ring is constructed 1-in. smaller in diameter than the one forming the top of the funnel (figure 5B). The funnel is then placed in this supporting ring and held over the penis area by one or more 2-in. webbing straps which are attached to the supporting ring and pass up the side and over the back of the steer and buckle or snap to the part of the strap which is attached to the opposite side of the ring. Branding cement is applied beneath the webbing strap on each side of the steer 6 in. from the supporting ring to prevent lateral movement of the funnel. Additional security measures are taken by attaching two straps that are 2 in. wide and 8 in. long to the front and rear portions of the supporting ring and to the belly of the steer with branding cement (figure 6). This harness arrangement makes possible the removal of the funnel from the supporting ring at will, by releasing the back strap and passing the funnel laterally through the supporting ring from either side of the animal.

This soft rubber may be easily torn by the rear feet of the animal, but can be satisfactorily protected by means of a heavy canvas apron supported

between the funnel and the animal's rear feet (figure 5C). The apron is constructed by sewing in a window sash cord, of sufficient length to tie over the animal's back, at the top of a 20 in. × 20 in. piece of heavy canvas. The bottom end of the apron is made secure by tacking it beneath a thin lath across the floor of the stand immediately behind the opening through which the funnel neck passes. The apron is then pulled into position against the animal's belly, between his feet and the funnel, by passing the rope ends up both sides of the animal and tying them anove the loin region (figure 6).

Figure 6. The steer urinal in position, showing attachments, and protective canvas apron.

This provides adequate protection for the funnel without discomfort to the animal in the prone or standing position.

Summary

The construction of a metabolism unit of simple design and operation is described which provides for the quantative separation and collection of feces and urine eliminated by steers and heifers. The unit including metabolism stall, equipment construction and operation is illustrated by labelled diagrams and photographs.

Literature Cited

Briggs, H. M. and W. D. Gallup. 1949. Metabolism Stalls for Wethers and Steers. JOURNAL OF ANIMAL SCIENCE 8: 479.

Forbes, E. B., J. W. Bratzler, A. Black and W. W. Braman, 1937. The Digestibility of Rations for Cattle and Sheep. Pa. Agr. Exp. Sta. Bul. 339.

THE INFLUENCE OF FEEDING THIOURACIL TO DAIRY BULL CALVES[1]

A. B. Schultze, I. L. Hathaway and W. J. Loeffel
Nebraska Agricultural Experiment Station

THE effect of feeding thiouracil on the fleshing and fattening of certain species of domestic animals has been rather widely investigated. Kempster and Turner (1945) showed that the feeding of thiouracil to broilers for a period of 2 to 4 weeks prior to marketing materially improved the carcass grade. Muhrer and Hogan (1945), Terrill *et al.* (1948) and Hale and associates (1948) noted increased fattening and more rapid rate of gain with the feeding of thiouracil to swine for a short period before marketing. The feeding of thiouracil to beef cattle and sheep has not resulted in any noticeable effect on the carcass grade, the rate of gain or fattening ability (Barrick *et al.*, 1948; Beeson and co-workers, 1948).

It often is unprofitable to feed dairy bull calves to a marketable condition. If by the use of thiouracil such calves could be made to reach a marketable condition in a short time, they would be of greater value as meat producers.

It was with this thought in mind that the study of the effect of feeding thiouracil to young calves was initiated.

Methods

Thirty-one young bull calves of the Holstein, Guernsey and Jersey breeds were used as experimental animals. Equal numbers of a breed were assigned to experimental and control lots. Thiouracil[2] was given once daily by capsule in amounts of 2.0 grams per calf per day beginning at 1½ weeks of age and increased to 3.0 grams per calf per day once daily at 7 weeks of age. This amount was administered until the calves were 15 weeks of age when they were slaughtered. The calves were killed 12–18 hours after receiving the last dose of thiouracil. The amount of thiouracil used was determined by estimating the amount that would be consumed if 0.1 per cent of the dry matter of the feed the calves consumed was thiouracil. While the experiment was in progress, Pipes and Turner (1946) showed that to maintain a satisfactory thiouracil level in the blood of calves, it should be administered twice daily. Therefore in the latter part of the experiment the calves were fed the calculated quantities of thiouracil twice daily, thus doubling the dosage.

Birth weight, slaughter weight, gain per week, carcass grade, dressing

[1] Published with the approval of the Director as Paper No. 498 Journal Series Nebraska Agricultural Experiment Station.

[2] Furnished by Lederle Laboratories.

percentage, and weights of the omentum, spleen, liver, brain, heart, thyroid, pituitary gland and testes were recorded for each calf. Hopper (1944) has shown that a high degree of relationship exists between the chemical composition of the wholesale rib and that of the entire carcass. Therefore a representative sample of flesh was obtained from a composite of the right and left rack. A chemical analysis[3] was made of this sample to determine the percentage of water, crude fat, and crude protein. Also the percentage of flesh and bone of the two racks was determined. The data obtained were analyzed statistically to determine the significance of the differences between the control and thiouracil fed calves. Relationships between certain criteria available in the data were determined on a breed basis.

Feeding experiments were also made to determine whether there was enough thiouracil in the meat of the calves to affect the body, thyroid, kidney or liver weights of growing rats. The ground meat from each calf was divided into 150 gram portions, wrapped in parchment paper and stored at zero degrees F. until fed.

Meat from a calf which had received thiouracil was fed to ten rats while a comparable group of animals was given the meat of a control calf. The amount of meat fed daily to each rat was increased from ten to thirty grams as the feeding trial advanced. The meat allowed each rat was weighed daily and added to two grams of the stock ration. This ration was composed of corn (74%), linseed oil meal (16%), casein (5%), yeast (2%), alfalfa (2%), calcium carbonate (0.5%), and sodium chloride (0.5%). These ingredients were ground, thoroughly mixed and five percent of butter was added. Each rat in a given experiment received the same amount of meat. However, the lengths of the feeding trials varied from 15 to 49 days depending upon the quantity of meat available. The amount of meat consumed per rat in the various experiments varied from 300–1290 grams. All rats received distilled water to which iodine was added, as suggested by Sure, 1923.

The rats used were males and averaged 82.5 grams in weight at the beginning of the feeding trial. All animals were housed in individual cages which were equipped with screen bottoms of one-half inch mesh. Eleven experiments were made in which 310 rats were used. One hundred sixty of these rats received meat from sixteen thiouracil fed calves while the other one hundred fifty rats were fed meat from the fifteen control calves.

Results

A comparison of thiouracil-fed and control calves with regard to the data obtained in this experiment is presented in table 1. There was no significant difference between the data obtained from the thiouracil-fed calves and

[3] Chemical analysis made by Dept. of Agr. Chemistry.

those from the control calves with the exception of the weight of the thyroids per 100 grams of body weight. In this case the thyroids of the thiouracil fed calves were statistically significantly larger than those of the controls. Since drugs such as thiouracil result in enlarged thyroids it is indicated that thiouracil in the dosages administered was effective in enlarging the thyroid in at least some of the calves. That the amount of thiouracil necessary to cause enlargement of the thyroid of individual lambs is quite variable has been noted by Barrick, Andrews, Beeson and Harper (1948).

TABLE 1. COMPARISON OF CONTROL AND THIOURACIL FED CALVES

Item	Means		Variance	
			Mean squares	
	Control	Thiouracil fed	Between group means[1]	Error[2]
Birth wt. (pounds)	83.0	83.3	0.63	904.0
Slaughter wt. (pounds)	236.77	224.62	961.0	459.0
Gain per week (pounds)	10.23	9.54	3.00	2.16
Dressing percentage	52.25	52.38	.12	5.33
Flesh on right and left racks (percentage)	74.63	74.51	.09	2.11
Water in flesh, percent	72.22	71.92	.56	1.399
Crude protein in flesh percent	18.80	19.14	.75	1.195
Crude fat in flesh percent	7.45	7.78	.72	2.63
Omentum gms/100# body wt.	143.0	163.1	2621.0	2938.0
Spleen gms/100# body wt.	126.2	152.1	4368.0	5411.0
Liver gms/100# body wt.	898.9	944.3	13389.0	3818.5
Brain gms/100# body wt.	142.5	145.0	42.0	800.7
Heart gms/100# body wt.	223.5	233.5	640.0	1595.5
Thyroid gms/100# body wt.	5.05	6.54	15.45*	1.75
Testes gms/100# body wt.	15.04	13.82	9.61	4.0
Pituitary mgs/100# body wt.	440.0	438.0	.10	3.5

[1] Degrees of Freedom = 1.
[2] Degrees of Freedom 14.
* $P = 0.05$.

Body weights of thiouracil and control calves were practically the same. Slaughter weight at 15 weeks of age of the thiouracil calves was 12.2 pounds less than that of the control animals. Dressing percentage based on the skinned carcass after chilling was very nearly the same for control and experimental calves, being 52.25 and 52.38 percent respectively. The percentage of flesh on the right and left racks was almost the same, being 74.63 percent for the controls and 74.51 percent for the thiouracil fed calves. None of these differences were significant statistically. Chemical analysis of a sample of meat procured from the right and left rack showed that the flesh

of thiouracil-fed calves contained 71.92 percent water, 19.14 percent crude protein, and 7.78 percent crude fat. The flesh of the control calves contained 72.22 percent water, 18.80 percent crude protein, and 7.45 percent crude fat. None of these differences were statistically significant.

Since detailed data were available for certain gland and organ weights and for percentage of fat in the flesh and the rate of gain, it was thought

TABLE 2. RELATIONSHIPS OF CERTAIN ORGAN WEIGHTS TO GAIN, AND PERCENT FAT IN FLESH

Items correlated	Group	Correlation Coefficient[1]
Thyroid wt/100# body wt. and gain per week	T.U.L. Fed	−0.486
	Control	−0.051
Thyroid wt/100# body wt. and percent fat	T.U.L. Fed	+0.603*
	Control	+0.297
Testes wt/100# body wt. and gain per week	All Calves	+0.434*
Testes wt/100# body wt. and percent fat	All Calves	+0.213
Pituitary wt/100# body wt. and gain per week	All Calves	−0.202
Thyroid wt/100# body wt. and liver wt/100# body wt.	T.U.L. Fed	+0.625*
	Control	+0.457
Thyroid wt/100# body wt. and heart wt/100# body wt.	T.U.L. Fed	+0.307
	Control	+0.485
Thyroid wt/100# body wt. and spleen wt/100# body wt.	T.U.L. Fed	+0.331
	Control	−0.210
Omentum wt/100# body wt. and percent fat	All Calves	+0.600**
Birth wt. and gain per week	All Calves	+0.0008
Gain per week and percent fat	All Calves	+0.072

[1] $r = .514$ for $P = 0.05$ for the T.U.L. fed or control groups alone.
* $P = 0.05$.
** $P = 0.01$.

that it would be of value to determine the relationship between certain items, such as organ and gland weights and the percentage of fat in the flesh and the rate of gain. Table 2 presents the relationships determined. Since there is a statistically significant difference between the thyroid weights of control and thiouracil-fed calves, relationships in which thyroid weights were concerned were divided according to control and thiouracil-fed groups. No significant relationship was found between the birth weight of the calf and the rate of gain up to 15 weeks of age. The relationships between rate of gain and the percentage of fat in the flesh, the thyroid weight per 100 pounds body weight and the spleen weight per 100 pounds of body weight, the pituitary weight and gain per week, and testes weight and percent fat in the flesh were not of statistical significance.

There was a negative correlation between thyroid weight and gain per

week and a positive correlation between thyroid weight and percentage of fat in the flesh. These correlation coefficients were of great enough magnitude to approach significance for the thiouracil fed group but not for the control group. This seems to indicate that when the calf was influenced by the feeding of thiouracil to the extent that its thyroid was significantly enlarged there resulted an increased deposition of fat in the flesh and a reduced rate of gain.

There was a statistically significant positive correlation between the omentum weight and the percent of fat in the meat. Lush (1926) found a

TABLE 3. THE EFFECT OF FEEDING MEAT FROM CONTROL AND THIOURACIL FED CALVES UPON THE BODY, THYROID, KIDNEY AND LIVER WEIGHTS OF GROWING RATS

Data observed	Means of group		Variance	
			Mean squares	
	Thiouracil	Control	Between group means[1]	Error[2]
	mgs.	mgs.		
Gain per gm. meat consumed	157.6	146.3	0.98[N.S.]	243.2
Thyroid wt. per 100 gms. body wt.	9.29	9.46	210.8[N.S.]	626.6
Liver wt. per 100 gms. body wt.	5185.6	5090.0	70.8[N.S.]	199.8
Kidney wt. per 100 gms. body wt.	1047.5	1038.5	0.60[N.S.]	4.45

[1] Degrees of Freedom = 1.
[2] Degrees of Freedom = 30.
N.S. = Not significant.

high degree of relationship between caul fat and the percent fat in the entire carcass. The relationship of testes weight per 100 pounds body weight and gain per week was of such magnitude as to approach significance at the 5 percent level. The biological significance of this is not apparent as the function of the testes before 15 weeks of age would be rather limited. There was significant positive correlation between thyroid weight and liver weight for the thiouracil-fed group.

The results obtained from feeding meat from the thiouracil-fed and control calves are shown in table 3. The rats which received the meat from the thiouracil fed calves made an average gain of 157.6 mgs. per gram of meat consumed while the control rats made a corresponding gain of 146.4 mgs. Difference between the average weights of the thyroid glands per 100 grams of body weight was only 0.17 mg. Differences of 8.9 and 95.6 mgs. were obtained respectively, in the average weight of the kidneys and livers per 100 grams of body weight. The analysis of variance of the gains in weight

and also of the gland weights showed that none of these differences were significant at the 5% level. These results appear to agree with those obtained by Pipes and Turner (1946), and Franklin, Boehne and Jukes (1947).

Discussion

A group comparison of the calves fed thiouracil and the control calves show that there was no significant influence of thiouracil feeding. The fact that the thyroids of the calves fed thiouracil were enlarged but not uniformly so seemed to indicate that thiouracil feeding was not equally effective in bringing about thyroid enlargement in individual calves. Thyroid size was positively correlated with per cent fat in the flesh and negatively correlated with the rate of gain in the thiouracil fed group and not in the control group. This fact seems to indicate that in the calves where thiouracil was effective, the feeding of thiouracil influenced the rate of gain negatively and increased the fattening process. Why the thiouracil dosage should vary in its effectiveness in influencing thyroid size is not clear. Wide variability in the effectiveness of rumen function of the individual calves in rendering the thiouracil inactive and variability in the liver of individuals to effect detoxification may be factors.

The level of thiouracil fed varied from 0.035 to 0.065 gram per kilogram body weight and may have been too low a dosage for many of the calves. Ely, Olson, and Reineke (1948) have shown recently that 0.1 gram per kilogram body weight must be fed to maintain an adequate level of thiouracil in the blood of ruminants. Therefore the dosage used in this experiment may have been too low to influence every calf although the fact that there was a significantly larger thyroid gland in the thiouracil-fed group compared with that in the control group indicated that the dosage was effective in at least some of the calves. That individual response to thiouracil was more important than dosage level for the range of dosage on a unit weight basis used in this experiment is made evident by the fact that there was no significant correlation between thyroid size and size of thiouracil dosage.

Apparently there was not enough thiouracil retained in the flesh of the thiouracil fed calves after a depletion period of 12–18 hours to affect in a significant way the body, kidney, thyroid, or liver weights of rats fed flesh from the calves receiving thiouracil as administered in this experiment.

Summary

Thiouracil feeding to young calves at a dosage level of from .035 to .065 gram per kilogram body weight did not influence the rate of gain, percent of fat in the flesh, nor size of organ weights except that of the thyroid. The

thyroid weight on a body weight basis was greater for the thiouracil fed calves than for the control animals.

There was a significant negative correlation between thyroid size and rate of gain and a significant positive correlation between thyroid size and percent of fat in the meat for thiouracil-fed calves but not for the control group.

The feeding of flesh from the thiouracil fed calves to rats did not influence significantly their body, thyroid, liver, or kidney weights when compared with a group of rats receiving flesh from the control calves. Apparently the amount of thiouracil retained in the flesh of thiouracil-fed calves was insufficient to affect the characters studied.

Literature Cited

Barrick, E. R., F. N. Andrews, W. M. Beeson and Claude Harper. 1948. Effect of Thiouracil and Similar Compounds on Feeder Lambs. JOURNAL OF ANIMAL SCIENCE 7: 539.

Beeson, W. M., F. N. Andrews and P. T. Brown. 1947. The Effect of Thiouracil on the Growth and Fattening of Yearling Steers. JOURNAL OF ANIMAL SCIENCE 6: 16.

Ely, Ray E., Kenneth J. Olsen and E. P. Reineke. 1948. Absorption and Elimination of Thiouracil in Ruminants. JOURNAL OF ANIMAL SCIENCE 7: 208.

Franklin, A. L., J. E. Boehne III, and T. H. Jukes. 1947. A Biological Method for Determination of Thiouracil in Tissues Using Radio-active Iodine. JOURNAL OF ANIMAL SCIENCE 6: 498.

Hale, F., G. I. Robertson, C. M. Lyman, and W. A. Wyatt. 1948. The Effect of Feeding Thyroprotein and Thiouracil in Fattening Rations for Duroc Swine. JOURNAL OF ANIMAL SCIENCE 7: 527.

Hopper, T. H. 1944. Methods of Estimating the Physical and Chemical Composition of Cattle. Jour. Agr. Res. 68: 239.

Kempster, H. L. and C. W. Turner. 1945. The Effect of Feeding Thiouracil on the Fleshing of New Hampshire Broilers. Poultry Sci. 24: 94.

Lush, J. L. 1926. Practical Methods of Estimating the Proportion of Fat and Bone in Cattle Slaughtered in Commercial Plants. Jour. Agr. Res. 32: 727.

Muhrer, M. E., and A. G. Hogan. 1945. Effect of Thiouracil on Growing Swine. Proc. Soc. Exp. Biol. Med. 60: 211.

Pipes, G. W. and C. W. Turner. 1936. The More Active Goitrogens as Fattening Agents for Livestock. Mimeograph Paper Presented at 38th Ann. Meeting Am. Soc. An. Prod. 5: 405.

Sure, Barnett. 1923. Dietary Requirements for Reproduction. 1. The Nutritive Value of Milk Proteins from the Standpoint of Reproduction. Jour. Biol. Chem. 58: 681.

Terrill, S. W., J. L. Krider, W. E. Carroll and J. S. Hamilton. 1948. Effect of Thiouracil on Rate and Efficiency of Gain of Swine. JOURNAL OF ANIMAL SCIENCE 7: 534.

THE HEREDITARY ASPECT OF EYE CANCER IN HEREFORD CATTLE[1]

R. R. Woodward and Bradford Knapp, Jr.
United States Department of Agriculture

THE incidence of eye cancer is probably higher in Herefords than in any other breed of cattle. Although this fact has long been a matter of concern among Hereford breeders, relatively little information is available as to the cause of the best methods of dealing with this problem. As a result the financial loss suffered by the industry is considerable. In addition to the loss in weight a considerably lower selling price per pound is received for livestock affected with eye cancer. In fact, under Bureau of Animal Industry meat inspection, some carcasses may be totally condemned. Many breeders have resorted to the practice of having a veterinarian remove the eye and the eyelids in order to keep a valuable animal. Frank (1943) states that the prognosis is usually favorable if this operation is performed soon after occurrence of the neoplasm.

Data and Discussion

The data were collected from the herd at the United States Range Livestock Experiment Station at Miles City, Montana, under cooperative projects with the Montana Agricultural Experiment Station. The cattle were all purebred Herefords, both registered and unregistered. Records of 1,566 cows retained in the herd until they were at least three years of age were used. The period covered by the study was from 1926 to 1949, inclusive. Cows were kept in the herd not longer than 11 years prior to 1943, and since that year were kept not longer than 10 years.

The determination of the influence of heredity on eye cancer was the principal objective of this study. No attempt was made to classify the cattle by amount of eye pigmentation as was done by Guilbert *et al.* (1948) although their findings would indicate that lack of pigmentation around the eye was a contributing factor in the occurrence of cancer.

During the 25-year period, 73 cows developed eye cancer, or an incidence of 4.7 percent in the 1,566 cows studied. Guilbert *et al.* (1948) found an incidence of 5.25 percent in a California herd. The ages of the cows at the time of their disposal as well as the percentage incidence of the eye cancer according to the number of cows retained in the herd in each age are shown in table 1.

[1] Contribution for the United States Range Livestock Experiment Station and Montana State College, Agricultural Experiment Station cooperating. Journal Series No. 225.

There was a definite increase in incidence of cancer at five years of age and again at seven years of age. After that the yearly occurrence increased only slightly. Only two of the 1,566 cows developed carcinomas at three years of age. It appeared that age was a contributing factor in the development of the lesions.

The experimental herd at the United States Range Livestock Experiment Station originated with the purchase of a group of purebred Herefords in 1926. Not all of these cows were registered but since that time they have always been bred to registered Hereford bulls. It was possible to trace the

TABLE 1. INCIDENCE OF EYE CANCER AND AGE OF DISPOSAL OF COWS

Age of cow in years	Number of cows affected	Percentage incidence in each age group
3	2	.1
4	3	.2
5	13	1.4
6	8	1.0
7	14	2.2
8	11	2.2
9	9	2.3
10	9	2.4
11	4	3.5

ancestry and history of both registered and unregistered cows back to the time of the original purchase except for two of the 73 affected cows. These two cows were from lines acquired in 1944.

These data were difficult to analyze statistically, but most of the evidence indicated that inheritance played a part in the incidence of the carcinomas. Fourteen of the 73 cows that developed eye cancer were mother-and-daughter pairs. As the history of the dams of the original cows and the future occurrence of eye cancer from daughters of some of the cows not culled was not known, this figure could be still higher. In one family in the herd every generations since the foundation cow has produced a case of eye cancer, including two cases in which both mother and daughter developed lesions. There were also four instances in which the half-sister of a cow with eye cancer produced a calf that was affected.

Further evidence of the influence of heredity in the development of eye cancer was obtained by the separation of the registered cows into lines of breeding. The first three lines used in the sire testing work at this station were studied. All were closed lines, two of which were started in 1934 and the other in 1938. About the same percentage of cows were retained in each line for an equal length of time. The total number of cows, the number of

cows that had eye cancer, and the percentage incidence of eye cancer, in each line are given in table 2.

The incidences of 4.7 percent in Line 1 and 4.8 percent in Line 3 were very close to the average incidence of 4.7 percent in the entire herd. However, there was over twice this percentage in Line 2. According to the chi-square test, the probability of such an incidence being due to chance was $<.02$. All of the cows in this line were either daughters or granddaughters of the one foundation sire.

Another sire also contributed heavily to the incidence of carninomas in the herd. On the 39 cows sired by two-half-brothers from the same sire,

TABLE 2. INCIDENCE OF EYE CANCER IN COWS FROM THREE LINES OF BREEDING

	Line 1	Line 2	Line 3
Total number of cows	257	88	42
Number of cows with eye cancer	12	9	2
Percentage of cows with eye cancer	4.7	10.2	4.8

seven, or 17.9 percent, developed eye cancer. There were only four carcinomas in the remaining 97 cows going into the herd during the same period. The latter incidence was about average for the herd. Again according to the chi-square test P equalled .01 when these data were analyzed.

Since there is apparent tendency for the incidence of eye cancer to be influenced by heredity, it should be possible in the future to reduce the number of animals affected. Various control measures are suggested by this knowledge. When the eye of a cow has been removed because of cancer, it would be advisable to sell both cow and calf as soon as the calf is of marketable age. Removal of the eye is often a sound practice, since the salvage value of the cow is usually increased and she can then be kept until the calf is old enough to be sold. In purebred herds in which the progeny of both sires and dams are known, offspring of affected mature animals should be culled. Certainly it would not be advisable to select as a herd sire any calf with a history of eye cancer in preceding generations.

Summary

According to the evidence presented, there appears to be hereditary susceptibility to eye cancer. In the herd studied the average incidence was found to be 4.7 percent and the percentage of incidence increased with the age of the animal. There were pronounced increases at five and again at seven years of age. Almost 20 percent of the animals affected were mother-

and-daughter pairs and in one family carcinomas have been found in each generation up to the present time. The progeny of two sires had an especially high percentage of lesions. In view of the findings described in this paper, certain control measures were suggested.

Literature Cited

Frank, E. R. 1943. Neoplasms of the Bovine Eye. Jour. Am. Vet. Assn., 102: 200.

Guilbert, H. R., A. Wahid, K. A. Wagon, and P. W. Gregory, 1948. Observations on pigmentation of eyelids of Hereford Cattle in relation to occurrence of ocular epitheliomas. JOURNAL OF ANIMAL SCIENCE. 7: 426.

REVISED ESTIMATES OF HERITABILITY OF ECONOMIC CHARACTERISTICS IN BEEF CATTLE

BRADFORD KNAPP, JR. AND R. T. CLARK
United States Department of Agriculture[1]

THE first estimates of heritability of economic characteristics in beef cattle were published by Knapp and Nordskog (1946, 1946a). These first estimates were based on only 177 steers from 23 bulls. Since that time, the number of steers available for study has increased more than four times, and therefore, much more reliable estimates may now be made. It is the purpose of this paper to present revised estimates of heritability based on the much larger number of steers available for study.

Knapp and Nordskog (1946) reported estimates of heritability of measures of growth and efficiency. They found birth weight by the half-sib correlation method to be 23 percent heritable, weaning weight 12 percent, weight at 15 months 81 percent, rate of gain in the feed lot 95 percent, and efficiency of gain 75 percent. By the parent-offspring regression method they found birth weight was 34 percent heritable, weaning weight 30 percent, weight at 15 months 94 percent, daily gain in the feed lot 97 percent, and efficiency of gain 48 percent. They recognized the relatively small sample they had to work with, and, though error of heritability was calculated, they suggested that the population studied was too restricted as to numbers to give reliable estimates.

Knapp and Nordskog (1946a) also reported estimates of heritability of live animal scores, grades, and certain carcass characteristics in beef cattle. Heritability of weaning score was 53 percent, slaughter grade was 63 percent, carcass grade 84 percent, area of eye muscle 59 percent, and carcass yield 1 percent. As in the previous study, the population was too limited to give reliable results.

Knapp and Clark (1947) reported that rate of gain in the feed lot was 72 percent heritable based on an estimate from 422 steers sired by 52 bulls. Heritability estimates of the three 84-day periods comprising the 252-day total feeding time indicated that the heritability of the first 84-day period was only 10 percent; the second, 54 percent; and the third and final 84-day period, 84 percent. Thus, they concluded that the genetic influence was more easily measured during the latter part of the feeding test.

Dawson, Phillips and Black (1947) reported that birth weight of Shorthorn

[1] Contribution from the Bureau of Animal Industry, United States Department of Agriculture, in cooperation with the Montana Agricultural Experiment Station. Paper No. 222 Journal Series. Certain phases of this study were carried on under the Research and Marketing Act of 1946.

cattle was 11 to 29 percent heritable. Tyler *et al.* (1948) in a study of heritability of body size in Holstein and Ayrshire cattle reported, for Holsteins, heritability estimates of 15 percent at 6 months of age, 35 to 65 percent at 18 months of age, and 30 to 60 percent at maturity, In Ayrshire cattle, heritability of size was estimated at 20 to 35 percent at 6 months of age, 30 to 60 percent at 12 months, 20 to 40 percent at 18 months, and 15 to 30 percent at 36 months. Body size was measured by live weight, height at withers, circumference of shin bone, heart girth, and width at hips.

Patterson *et al.* (1949) reported on 7 years' feeding experiments in Texas where 6 to 10 progeny per sire were fed growing rations under similar conditions. On 814 young bulls tested under this program they observed an intra-year half-sib correlation of 0.260 for rate of gain in the feed lot. This would indicate a heritability in excess of 100 percent. They suggest that the high estimate may be due to similar pretest environmental conditions of those calves within each sire group and the different pretest conditions of groups of calves from different breeders.

Materials and Methods

All animals used in this study were Herefords produced at the United States Range Livestock Experiment Station, Miles City, Montana, or at the North Montana Branch Station, Havre, Montana, under cooperative projects between the United States Bureau of Animal Industry and the Montana Agricultural Experiment Station. All calves were dropped on the range at both stations during an 8 weeks' period in March, April and May of each year. The bulls and steers produced at Miles City were all fed at Miles City. Those steers produced at Havre were shipped at weaning time to the Montana Agricultural Experiment Station at Bozeman, Montana, for feeding.

The feeding and management of all calves at both stations were the same during any one year though the concentrate ration and some management practices varied between years.

The steers used in this study were the result of random mating from random selected females maintained on each station for test herds. During the breeding season, each bull was bred to 25 to 30 random selected cows from these test herd groups. Eight steer calves, if available, were randomly selected from the entire steer calf crop from each sire, and were placed on feed in the record of performance barns. Since these test herds were resorted each year the probability of any pretest variation in treatment materially affecting the outcome is rather remote. The test herds were maintained in separate pastures only during a six weeks breeding season and otherwise the cows were always in the same pastures during the entire year. The bulls

were produced from the line herds and were not the result of random mating but rather matings were made on the basis of performance records and relationship to the bull.

All calves were weaned in the fall on the same day at both stations. The bulls were fed for a period of 196 days after weaning and the steers for 224 to 273 days, but all steers were fed the same length of time in any one year.

Two methods were used to estimate heritability. These were: (1) half-sib correlations obtained from analyses of variance, and (2) regressions of progeny average on sire obtained from covariance analyses. All analyses of variance were based on intra-year and intra-station variances. The two covariance analyses are not corrected for year and are for only one station but when the effect of year was taken out, the estimates were considerably higher than those shown. Although, there were several lines of breeding represented in the data, the removal of variance due to line, materially increased the estimates of heritability.

Results and Discussion

Heritability estimates based on the half-sib correlations are shown in table 1. These estimates are lower in some cases than those reported by Knapp and Nordskog (1946 and 1946a) and are more in line with those reported by Tyler *et al.* (1948). The greatest changes were in gain in the feed lot and carcass grade.

The variations in number of progeny groups are due to the fact that certain information on some of the groups was not available in the earlier years of steer feeding.

TABLE 1. REVISED HERITABILITY ESTIMATES, ESTIMATED LOWER FIDUCIAL LIMITS OF HERITABILITY AND NUMBER OF PROGENY GROUPS FOR EACH ECONOMIC CHARACTERISTIC IN BEEF CATTLE. INTRA-YEAR AND INTRA-STATION ANALYSIS

Economic characteristic	Number of progeny groups	Estimated heritability percent	Lower limits of heritability[1] percent
Birth weight	110	53	26
Weaning weight; age corrected	110	28	7
Final feed-lot weight—15 months	110	86	54
Gain in the feed lot	110	65	37
Weaning score	86	28	4
Slaughter steer grade	104	45	19
Carcass grade	104	33	10
Area of eye muscle	64	68	31

[1] Estimates on the lower fiducial limits of heritability were calculated as outlined in the previous report (see Knapp and Nordskog 1946 and 1946a).

The estimate of heritability of birth weight by half-sib correlation became much higher than that previously reported. Trends in birth weight over the past few years show that the average birth weight is heavier than it was 10 years ago, in spite of the fact that there has been no conscious selection for heavier calves at birth. At the same time there are also more marked differences in birth weight between progeny groups than in years past.

Heritability estimate of weaning weight is higher than previously reported. Final feed lot weight is estimated slightly higher than previously reported and is much higher than similar estimates in swine (Nordskog *et al.*, 1944). This estimate is higher than that reported in dairy cattle (Tyler *et al.*, 1948). The estimate of heritability of rate of gain in the feed-lot is much lower than previously reported. It does, however, remain quite high in comparison to that in swine (Nordskog *et al.*, 1944). Estimates of heritability of quality and conformation scores are still lower than those of growth and are also lower than those previously reported.

Heritability estimates of weight at 15 months and rate of gain in the feed lot were also made by the use of sire:offspring regression. In figure 1 is shown the scatter diagram of 72 sires and their offspring average and the regression line. These 72 sires were all that were available in which feed, weight and gain records on the sire and on the offspring are known. Estimates of heritability were as follows:

Weight at 15 months of age = 92 percent
Rate of gain on feed = 77 percent

In both instances, the estimates are a little higher than those obtained from the half-sib correlation method.

Heritability estimates of weight for age remain relatively high at 15 months of age and appear to be at the lowest point at weaning time. Birth weight is highly heritable but as the suckling period progresses the relative influence of heredity becomes less. This is due to the effect of the milk production of the mother on the nutrition of the calf. Weaning weight is an expression of several factors, the most important of which are the milk production of the cow and the growth ability of the calf. Obviously a calf with poor growth potentialities cannot make full use of the mother's milk but a calf with good growth ability may be held back by the lack of milk from its dam. The many possible interactions of growth ability of the calves and milk production of the dams would tend to make weight at weaning the lowest point in the heritability curve. Post weaning growth is obviously more heritable and it is during this period that selection for growth ability can be accomplished. This fact has been recognized for the past several

years and has been the basis of the Bureau of Animal Industry's record of performance program with beef cattle.

It can be concluded that heredity plays a major part in the determination of post-weaning growth rate. Since this is true, individual performance can be used as the basis for predicting progeny gains or weights. Figure 1 shows this relationship for weight at 15 months of age. Yearly variations have not been eliminated in plotting the points in figure 1. The regression coefficients for weight were 0.476 and for daily gain 0.406. The errors of estimate were found to be 46 pounds for final feed lot weight and 0.15 pound for daily gain.

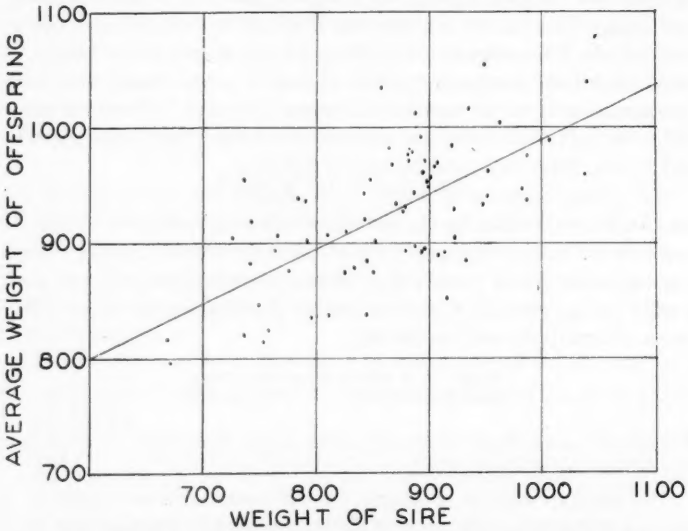

Figure 1. Relationship between weight of sire and weight of offspring at 15 months of age.

It also can be concluded that since the heritability estimates for growth-measures remain high, greater progress may be expected by the use of sib testing than by the slower progeny test methods employed at first.

Summary

Revised heritability estimates based on the progeny of 64 to 110 Hereford sires are presented. These studies were conducted at the U. S. Range Livestock Experiment Station, Miles City, Montana, in cooperation between the Bureau of Animal Industry and the Montana Agricultural Experiment Station. The following estimates were obtained by the half-sib correlation

method: Birth weight 53; weaning weight 28; final feed lot weight at 15 months 86; gain on feed 65; weaning score 28; slaughter steer grade 45; carcass grade 33; and area of eye muscle 68 per cent. Estimates based on sire: offspring regression for final weight at 15 months were 92 percent and for rate of gain in the feed lot were 77 percent. Lower fiducial limits of heritability ($P = .01$) based on the half-sib correlation method were: birth weight 26; weaning weight 7; final weight 54; gain in the feed lot 37; weaning score 4; slaughter steer grade 19; carcass grade 10; and area of eye muscle 31 percent. These figures indicate the relatively high influence of heredity in determination of growth after weaning. Growth measures were more highly influenced by heredity than were measures of quality and conformation.

Literature Cited

Dawson, W. M., Ralph W. Phillips and W. H. Black. 1947. Birth Weight as a Criterion of Selection in Beef Cattle. JOURNAL OF ANIMAL SCIENCE 6: 247.

Knapp, Bradford Jr. and Arne W. Nordskog. 1946. Heritability of Growth and Efficiency in Beef Cattle. JOURNAL OF ANIMAL SCIENCE 5: 62.

Knapp, Bradford Jr., and Arne W. Nordskog. 1946a. Heritability of Live Animal Scores, Grades and Certain Carcass Characteristics in Beef Cattle. JOURNAL OF ANIMAL SCIENCE 5: 194.

Knapp, Bradford Jr. and R. T. Clark. 1947. Genetic and Environmental Correlations Between Growth Rates of Beef Cattle at Different Ages. JOURNAL OF ANIMAL SCIENCE 6: 174.

Nordskog, Arne W., R. E. Comstock and L. M. Winters. 1944. Heredity and Environmental Factors Affecting Growth in Swine. JOURNAL OF ANIMAL SCIENCE 3: 257.

Patterson, R. E., J. H. Jones, J. J. Bayles and R. V. Turnbough. 1949. Performance-Testing and Progeny-Testing of Beef Breeding Stock as an Aid to Selection. JOURNAL OF ANIMAL SCIENCE 8: 608. (Abstract).

Tyler, W. J., George Hyatt, A. B. Chapman and G. E. Dickerson. 1948. The Heritability of Body Size of Holstein-Friesian and Ayrshire Cattle. JOURNAL OF ANIMAL SCIENCE 7: 516 (Abstract).

THE REPEATABILITY OF PERFORMANCE OF SEVERAL HEREFORD SIRES AS MEASURED BY PROGENY RECORDS

R. R. Woodward and R. T. Clark
U. S. Department of Agriculture

IT IS important in the record-of-performance testing of beef cattle to determine whether the relative performances of different sires will be similar when bred to different cow herds and to herds which are subjected to different environmental conditions and management procedures. This experiment was initiated in an attempt to answer that question.

Materials and Methods

Experimental work reported in this paper was conducted at the United States Range Livestock Experiment Station at Miles City, the North Montana Branch Station at Havre, and the Montana Agricultural Experiment Station at Bozeman, Montana. The steer progenies of eleven bulls were fed out at both Miles City and Bozeman. The bulls were all purebred Herefords raised in the Miles City herd. The first winter after birth they were individually-fed at Miles City and the following summer bred to different groups or "herds" of cows. The cows in each herd were randomly selected from balanced age-groups and each bull was placed in a pasture with only the cows assigned to his herd. The steers from these matings were then individually-fed at Miles City as calves to determine their record of performance. The bulls were then taken to Havre, generally as two-year-olds, and the same breeding procedure was followed at that station with the North Montana Branch Station herd of grade Herefords. The second steer progenies were shipped to Bozeman and fed as calves. The records of the performance of these two progeny groups serve as the basis of comparison between the two tests. In table 1 are shown the names of the bulls and the years in which their calves were tested at the two stations.

The calves were started on feed shortly after weaning. A preliminary trial of approximately two weeks preceded the regular trial for the purpose of allowing the calves to become accustomed to the ration and feed lot. If available, eight steers were used from each sire group as recommended by Knapp *et al.* (1942). The initial and final weights were the average of three successive weighings made at the beginning and end of the feeding trial. Intermediate weights were taken every 28 days.

Contribution from the United States Range Livestock Experiment Station, Miles City, Montana, and Montana State College, Agricultural Experiment Station cooperating. No. 226 Journal Series.

The rations fed at Miles City and Bozeman were different, although the nutritive ratio was the same at both stations. Corn was used for the grain portion of the concentrate at Miles City and barley was fed at Bozeman. The roughage fed at both stations was alfalfa, except for the last two years when native hay was fed at Bozeman.

The principal variables in methods of testing were the length of the

TABLE 1. REGISTERED NAMES OF BULLS TESTED AND YEAR USED AT MILES CITY AND BOZEMAN

Registered name of bull	Brand	Year tested at Miles City	Year tested at Bozeman
Baron Domino	M.C. 13	1940	1942
Basil Domino	M.C. 16	1941	1942
Brian Domino	M.C. 20	1942	1944
Bourbon Domino	M.C. 21	1942	1944
Clayton Domino	M.C. 28	1942	1943
Baldwin Domino	M.C. 31	1942	1945
Baxter Domino	M.C. 32	1942	1944
LIB Domino 1st	M.C. 43	1944	1945
LIB Domino 2nd	M.C. 44	1943	1944
Baldwin Domino 2nd	M.C. 47	1944	1945
A-A Domino 2nd	M.C. 57	1944	1945

feeding periods which ranged from 197 to 281 days, and the rations fed. Other variables were the cow herds, environmental conditions and years of testing.

Results and Discussion

Four factors were analyzed in comparing the records of calves born at Miles City and Havre. They were: birth weights, average daily gains from birth to weaning, average daily gains in the feed lot and efficiency of gain in the feed lot. The average weights and gains by sire groups are shown in table 2.

The calves born at the Havre station averaged a little heavier than did those dropped at Miles City. Six of the eleven tested bulls sired calves at Havre that were heavier than those they sired at Miles City. The remaining five bulls had heavier calves at Miles City. In each case the difference was slight.

When an analysis of variance was made between the birth weights of the calves born at Miles City and Havre, the only significant difference obtained was between sire groups, in which P was less than .05. There was not a significant difference in birth weights between stations, nor was there a sire $\times$ station interaction.

As was expected, a greater station influence was evident in average daily gains from birth to weaning than in birth weights. Calves from all but two of the sires made greater gains from birth to weaning at Havre than they did at Miles City. Weaning weights at Havre have averaged heavier than at Miles City, although the difference in weights was not significant. The number of days between birth and weaning has averaged approximately the same at both stations. The difference in average daily gains can probably be

TABLE 2. BIRTH WEIGHTS, AVERAGE DAILY GAINS FROM BIRTH TO WEANING, AVERAGE DAILY GAINS AND EFFICIENCY OF GAINS IN THE FEED LOT (IN POUNDS) OF STEERS FROM 11 SIRES

Sire number	Birth weight of steers at—		Average daily gain birth to weaning at—		Average daily gain in feed lot at—		Efficiency of gain** in feed lot at—	
	Miles City	Havre	Miles City	Havre*	Miles City	Bozeman	Miles City	Bozeman
13	74.3	80.4	1.73	1.77	1.68	2.19	563.5	492.0
16	81.8	77.0	1.86	1.79	1.80	2.22	558.6	496.8
20	80.6	82.6	1.98	1.94	2.06	1.68	518.4	512.9
21	78.6	86.5	1.81	1.91	2.01	1.96	511.7	460.6
28	85.1	83.5	1.98	2.05	2.09	2.30	524.4	502.9
31	81.5	80.1	1.77	1.88	1.98	1.73	495.1	546.8
32	79.4	81.5	1.87	1.92	1.89	1.97	518.4	483.2
43	81.4	81.3	1.79	1.84	1.86	1.75	552.5	540.9
44	89.9	83.8	1.88	1.91	2.28	1.86	517.6	495.4
47	77.5	82.0	1.66	1.87	1.84	1.59	538.3	594.5
57	83.6	89.0	1.87	2.11	1.98	1.93	541.2	506.3

* These steers shipped to Bozeman to be fed shortly after weaning.

** This figure represents the pounds of T.D.N. required to produce 100 pounds of gain.

attributed to more favorable conditions at Havre, including a more product ive range, cooler temperatures during the summer and shorter distances to water on the range.

The analysis of variance for average daily gain from birth to weaning showed a significant difference between sire groups and between stations. There was not a significant sire × station interaction. This meant that sires producing fast gaining calves at one station tended to do likewise at the other station.

The average daily gains of the steers in the feed lot were evidenced by pronounced variations in the mean performance of progeny from the same sire. One bull sired steers that gained .51 pound more per day at Bozeman than at Miles City.

There was no significant difference between stations in average daily gains in the feed lot but there was a significant difference between sire groups and a significant sire × station interaction. This indicated that some sires tested high at Miles City and low at Bozeman while other sires were

high at Bozeman and low at Miles City. However, some sires had consistently good records at both stations. A possible explanation of the sire × station interaction is that it was due to year effects, since the same sire was not always used the same year at both stations.

In support of this contention the results of the tests on three sires can be cited (No. 43, 47 and 57). They were all tested in 1944 at Miles City and in 1945 at Bozeman. Their relative ratings were the same at both stations.

There was considerable similarity in the performance of the various sire groups in rate and efficiency of gain in the feed lot. However, most of the sires had faster gaining calves at Miles City, but all except two of the sire groups made more efficient gains at Bozeman.

The results of an analysis of variance on efficiency of gains in the feed lot at Miles City and Bozeman show significant differences between sire groups and between stations. There was also a significant sire × station interaction. Practically the same results occurred in this analysis as were obtained when the average daily gains in the feed lot were analyzed. The exception was that there was no significant difference between stations in average daily gains, but there was a significant difference between stations in efficiency of gains.

The similarity in results between rate and efficiency of gain of the sire groups was to be expected. Winters and McMahon (1933) and Black and Knapp (1936) both found a high correlation between rate and efficiency of gain in the feed lot. The latter reported a correlation coefficient of .88 between efficiency of gain and rate of gain from weaning to slaughter and a correlation coefficient of .89 between efficiency of gain and rate of gain from birth to slaughter.

Summary

There was no significant difference in birth weights between calves sired at Miles City and calves sired at Havre, but there was a barely significant difference between sire groups.

Calves at the Havre station averaged significantly faster gains from birth to weaning than did the calves at the Miles City Station. There was also a significant difference in average daily gains from birth to weaning between sire groups. Sires producing fast gaining calves at one station tended to do the same at the other station.

There was no significant difference between stations in average daily gains in the feed lot. There was a significant difference between sire groups and a sire × station interaction. Hence, some of the sire groups made fast gains at Bozeman and slow gains at Miles City. With other sire groups the reverse was true.

An analysis of the efficiency of gains in the feed lot showed that the steers

fed at Bozeman averaged significantly more efficient gains than did the steers fed at Miles City. The remainder of the analysis showed results similar to those obtained from the study of rate of gain in the feed lot. There was a significant difference between sire groups and a sire × station interaction.

It was evident from these studies, that, in a broad program of record of performance testing of beef cattle, procedures should be standardized and refined as much as possible to eliminate certain variables that may affect comparative sire ratings.

Literature Cited

Winters, L. M. and Harry McMahon, 1933. Efficiency Variations in Steers. Minnesota Agr. Exp. Stat. Bul. 94: 28 pp.

Black, W. H. and Bradford Knapp, Jr., 1936. A Method of Measuring Performance in Beef Cattle. Proc. Am. Soc. An. Prod. 72–77.

Knapp, Bradford, Jr., Ralph W. Phillips, W. H. Black, and R. T. Clark, 1942. Length of Feeding Period and Number of Animals Required to Measure Economy of Gain in Progeny Tests of Beef Bulls. JOURNAL OF ANIMAL SCIENCE. 1: 283.

CAUSES OF VARIATION IN LENGTH OF GESTATION IN DAIRY CATTLE[1]

S. M. Jafar, A. B. Chapman and L. E. Casida[2]
University of Wisconsin

SOURCES of part of the variation in the length of gestation periods have been identified. Sex of the young has been reported to have an affect on gestation length by Knott (1932), Knoop and Hayden (1934), and Littlewood (1937) in cattle and by Uppenborn (1933) in the horse. No effect of sex was observed in sheep (Kelley, 1943; Terrill and Hazel, 1947) and in swine (Carmichael and Rice, 1920). Some studies have indicated an effect of age of the cow on the gestation (Knott, 1932; Knoop and Hayden, 1934) but others (Copeland, 1930; Knapp *et al.*, 1940) report there is no effect. Knapp *et al.* (1940) and Terrill and Hazel (1947) indicate that their data give no evidence of an effect of the weight of dam on the length of gestation in cattle and sheep, respectively. A positive correlation of the birth weight and the length of gestation has been observed in cattle (Knapp *et al.*, 1949), sheep (Phillips, 1928; Chapman, 1931) and swine (Lush *et al.*, 1934). Alexander (1950) reports a somewhat shorter gestation period preceding summer calvings but others (Copeland, 1930; Knapp *et al.*, 1940) have stated that their data did not show any effect of season of calving on the length of gestation.

Several studies have indicated an influence of the sire of the calf on the length of gestation (Knott, 1932; Rife *et al.*, 1943; Rife, 1948; Alexander, 1950). Terrill and Hazel (1947) have stated that "the heredity of the lambs exerts a strong influence upon the length of gestation, augmented further by individual differences between ewes. . . ."

Data Studied

The data for this study were collected from a herd of Holstein-Friesian cattle belonging to the Wisconsin State Department of Public Welfare (Winnebago State Hospital) during the years 1941–1945. The cows were examined in most cases at 35–49 days[3] after breeding, a stage at which an error of about 21 days in the breeding date would be easily detectable because of the rapid embryonic growth rate (Wisnicky and Casida, 1948).

[1] Paper No. 431 from the Department of Genetics. Published with the approval of the Director of the Agricultural Experiment Station.

[2] The authors are grateful to Dr. W. Wisnicky and Mr. Tom Webster for their assistance in the collection of data. They also wish to acknowledge the help of Dr. J. F. Crow in the statistical analysis.

[3] All of the pregnancy examinations were made by Dr. W. Wisnicky of the Department of Veterinary Science and by one of the authors (L.E.C.).

This made it possible in most cases to tell by which breeding a cow settled if she was bred at two or more consecutive heat periods.

All gestations that resulted in dead calves or calves that died within one week of birth were excluded from this study. Gestations resulting in multiple births were also excluded because of the small numbers of such gestations. No records were omitted on the basis of the length of gestation. There was a total of 384 gestation periods used, with an average length of gestation (interval from day of breeding to day of calving) of 278.2 days and a standard deviation of 4.8 days. Individual gestations ranged from 259 to 294 days.

Results

Bang's Test

Some of the gestation periods of cows infected with Brucellosis resulted in dead fetuses and hence were not used. The gestation periods resulting in living calves from cows which reacted positively to Bang's test were compared with those which did not react. No significant differences were found.

Sex of calf, calving sequence and age of dam

There were disproportionate numbers in the sex and calving sequence classes. The method of expected subclass numbers (Snedecor and Cox, 1935)

TABLE 1. ANALYSIS OF VARIANCE OF GESTATION PERIODS FOR SEX AND CALVING SEQUENCE (METHOD OF EXPECTED SUBCLASS NUMBERS)

Source of variation	Degrees of freedom	Mean square	Variance components	Variance	Percent of variance
Between sexes (*A*)	1	323.8**	$191V_A+40V_{AB}+V_W$	268.00	92.3
Between calving sequence (*B*)	4	33.8	—	—	—
Sex × calving sequence (*AB*)	4	53.0*	$38V_{AB}+V_W$	0.84	0.3
Within subclasses	374	21.4	V_W	21.40	7.4

** $P<0.01$.
* $P>0.01<0.05$.

was therefore used to analyse the data for the effects of these variables on gestation period. The mean squares for sex and the sex × calving sequence interaction were significant but the mean square for calving sequence was not, (table 1). Since the interaction was found to be significant the differences between calving sequences were analyzed separately for the two sexes, (table 2). Only the gestations in which female calves were carried showed a significant effect of the calving sequence, but there was no obvious trend. The regression of gestation length on calving sequence was studied for the

female calves. It was found to be non-significant. Male calves were carried on the average 1.97 days longer than the female calves. This difference was highly significant.

Year and season of calving

An intrasire analysis of the effects of the year and season on the length of gestation (corrected for sex and calving sequence) was made on the records of mates of the four sires which furnished enough data for study. No effect of year or season was indicated.

TABLE 2. NUMBERS AND MEANS OF GESTATION LENGTHS ACCORDING TO SEX OF THE CALF AND THE CALVING SEQUENCE OF DAM

Calving sequence	Male		Female	
	Number	Mean	Number	Mean
1	54	278.7	52	276.5
2	37	279.6	34	276.5
3	37	279.6	37	279.0
4	28	279.7	28	275.8
5 and over	46	278.3	31	278.6
Total	202	279.0	182	277.0
Mode		278.0		277.0
F (Between calvings)		0.8		3.4*

* $P > 0.01 < 0.05$.

Size of dam

A significant correlation of 0.23 ± 0.14 was obtained between the length of gestation (unadjusted for calving sequence) and heart girth on 92 dams. When the length of gestation was adjusted for sex and calving sequence, and heart girth was adjusted to a mature equivalent, the correlation was non-significant.

Correlation of gestation length and birth weight of calf

The correlation of gestation length and birth weight for 76 calves was 0.61 ± 0.09 in the unadjusted data, whereas for the sex adjusted data it was 0.52 ± 0.10.

Effect in inbreeding

The effect of inbreeding on the length of gestation was estimated from the intrasire partial regressions of gestation length on the inbreeding of the calf,

holding the inbreeding of the dam constant, (column 3, table 3) and on the inbreeding of the dam, holding the inbreeding of the calf constant, (column 4). Cows were inbred up to 25 percent and the calves up to 31 percent. The regressions did not show a significant departure from homogeneity in either column. The average intrasire regression for each column was non-significant.

Heritability of the length of gestation

The length of gestation was adjusted for sex and calving sequence before studying its heritability. The paternal half-sib correlation (intrauterine interval of calves sired by the same sire but carried by different dams), maternal half-sib correlation (intra-uterine interval of calves carried by the same dam in different pregnancies, sired by different sires), intrasire regression of offspring on dam (the number of days the calf is carried by its dam on the number of days the dam was carried as a calf by her dam), and full-sib correlation (intra-uterine interval of calves by the same sire and dam, carried by the same dam in different pregnancies) were used to estimate the heritable part of variation in the length of gestation and the relative importance of the genetics of the calf and of the dam. The correlations and regression used in this analysis are given in table 4.

TABLE 3. PARTIAL REGRESSIONS OF GESTATION PERIODS (Y) ON THE INBREEDING OF THE CALF (F) HOLDING THE INBREEDING OF THE DAM (F') CONSTANT ($b'_{YF \cdot F'}$) AND THE PARTIAL REGRESSIONS OF GESTATION PERIODS ON THE INBREEDING OF THE DAM, HOLDING THE INBREEDING OF THE CALF CONSTANT ($b'_{YF' \cdot F}$) BY SIRES

Sire (of calf)	No.	$b'_{YF \cdot F'}$	$b'_{YF' \cdot F}$
1	106	−0.06	−0.14
2	28	+0.06	+0.09
3	26	−0.32	−0.70
4	24	+0.18	−0.15
5	17	+0.20	−0.29
6	15	+0.06	+0.17
7	16	+0.42	+0.56
8	14	+0.37	+0.02
9	50	—	−0.13[1]
10	51	—	+0.24[1]
11	32	—	+0.17[1]
Total	379	−0.01	−0.06

[1] Simple correlation instead of partial regression because the calves were not inbred.

Since a few sires were used on a large number of cows, the maternal half

sib correlation was studied in a population of paternal half-sibs. The estimate of maternal half-sib correlation in this case was 0.23 ± 0.08. From this the maternal half-sib correlation in a random bred population[4] was estimated as 0.29 ± 0.08.

A paternal half-sib correlation could arise through partial similarity in the genotypes of the calves. A maternal half-sib correlation could result not only from a like degree of autosomal genotypic similarity in the calves but also from additional similarity due to common sex-linked genes and common

TABLE 4. CORRELATION COEFFICIENTS AND THE BREAKDOWN OF THE VARIANCE INTO POTENTIAL BIOLOGICAL COMPONENTS

Relationship between calves	No.	Correlation coefficient	Potential biological components	
			Calf[1]	Dam[2]
Paternal half-sibs	348	0.08**	$\frac{1}{4}g_0^2+\frac{1}{16}i_0^2$	
Maternal half-sibs	144	0.29**	$\frac{1}{4}g_0^2+\frac{1}{16}i_0^2$	$g_d^2+i_d^2+d_d^2+e_d^2$
Regression of offspring on dam	108	0.19*	$\frac{1}{2}g_0^2+\frac{1}{4}i_0^2$	$\frac{1}{2}g_d^2+\frac{1}{4}i_d^2$
Full sibs	34	0.41**	$\frac{1}{2}g_0^2+\frac{1}{4}i_0^2+\frac{1}{4}d_0^2$	$g_d^2+i_d^2+d_d^2+e_d^2$

** $P<0.01$.

* $P>0.01<0.05$.

[1] Portion of variance effective through the calf assignable to:

Additive gene effects of calf	$g_0^2=0.32$
Epistatic deviations from additive scheme	$i_0^2=0.00$
Dominance deviations from additive scheme	$d_0^2=0.16$

[2] Portion of variance effective through the dam assignable to:

Additive gene effects	$g_d^2=0.06$
Epistatic deviations from additive scheme	$i_d^2=0.00$
Dominance deviations and permanent maternal environment	$d_d^2+e_d^2=0.15$

maternal factors (cytoplasmic and uterine) in maternal half-sibs. If it is assumed that length of gestation is not dependent on major sex-linked genes then the difference between the maternal and paternal correlations should give an estimate of the maternal effects. The genotypic similarity of the calves whose records are used in these correlations would, on the average, result from one-fourth of the gene effects classified as additive and about one-sixteenth of those classified as epistatic deviations from the additive scheme (Wright, 1935). Intrasire regression of offspring on dam would be composed of one-half of the additive and about one-fourth of the epistatic fraction of variance acting through the genotype of the calf and a similar fraction acting through the hereditary maternal characteristics. Correlation of the full-sibs

[4] Based on the formula $r=r_m+r_p-r_m r_p$

where

r = correlation of maternal half-sibs in random bred population.

r_m = correlation of maternal half-sibs in a population of paternal half-sibs.

r_p = correlation of paternal half-sibs in a random bred population.

would be comprised of one-half of the additive, one-fourth epistatic and one-fourth dominance deviations acting through the calf and all of the hereditary and "permanent" non-hereditary maternal effects.

Since there were only four of these relationships (correlations and regression) and the number of biological components to be determined was seven (table 4), it was not possible to solve the equations simultaneously without reducing the number of unknowns. To do this the "permanent" non-hereditary effects and the dominance deviations in the dam were lumped together and it was assumed that there were no epistatic effects operating through the dam or the calf. On this basis the additive scheme accounted for

TABLE 5. RELATIVE IMPORTANCE OF SOURCES OF VARIATION IN GESTATION LENGTH

Source of variance		Percentage of variance
Sex of calf		28.6
Sex × calving sequence		0.1
Genotype of calf within sexes		
a. Additive	32.0	
b. Dominance deviations	16.0	
		48.0
Permanent maternal characteristics		
a. Additive	6.0	
b. Dominance deviations and permanent environment	15.0	
		21.0
Residual		2.3
Total		100.0

32 percent of the variation ascribed to the calf itself and the variance due to dominance deviations from the additive scheme explained another 16 percent of the variation assignable to the calf. The genotype of the calf (within sexes) was thus responsible for 48 percent of the variance. Maternal characteristics were responsible for 21 percent of the variance—six percent additive gene effects, and 15 percent permanent environment and dominance deviations.

Table 5 shows the relative importance of all the genetic and environmental sources of variation analyzed on the basis of the assumptions given.

Discussion

The results show very clearly that male calves are gestated longer than females. Analysis of the data within the sexes indicated a significant effect of calving sequence on gestations of female calves but not of males. The reason for this is not clear. It may be that there is a maximum gestation

length compatible with viability and that the male calves are closer to this maximum by virtue of their sex. Calving sequence, therefore, may not have an appreciable effect over and above this characteristically greater length of gestation for living male calves.

Birth weight and the length of gestation have a high positive correlation. This study throws no light on the causal relationship of the two characteristics. An earlier study in sheep by Chapman (1931) showed that a significant positive correlation between the length of gestation and birth weight became smaller and insignificant when the direct effects of age and weight of dam, and number born on birth weight were removed. From this it could be postulated that variation in length of gestation does not have a direct effect on variation in birth weight. Hence, common causes may be considered as responsible for variation in both of them. Any factor causing a delay in parturition should also cause an increase in the birth weight by allowing a longer time for growth of the fetus (Wright, 1934). Birth weight on the other hand, may ultimately become a factor in bringing about parturition by virtue of a direct effect of size or weight of the fetus upon the parturition mechanism.

The breakdown of variation into its biological components is only approximate because of the large sampling errors of the correlation coefficients, and because the expected fractions due to additive gene effects and dominance and epistatic deviations from the additive scheme have not been established experimentally but rest on certain assumptions. Based on these assumptions and assuming further that the effects of the dam and of the fetus are independent of each other, it may be concluded that the combined heredity of the calf (excluding sex) and the dam was responsible for 50–70 percent of the total variance out of which 38 percent was due to additive gene effects. Genotype (including sex) of the calf was responsible for 77 percent of the variance. On the basis of these figures the genotype of the calf is about three times as important as the characteristics of the dam. Some workers have emphasized the importance of the dam whereas others have stated that genotype of the calf is all important (Rife *et al*, 1943, Rife, 1948). The results of this study point to the influence of the dam on the length of gestation through two channels—through her own characteristics and through her contribution of a sample half of her genes to the fetus. Maternal characteristics were responsible for 21 percent of the variation and in addition the dam's genetic contribution to the similarity of her calves accounted for eight percent. Thus the similarity in the gestations of the same cow, i.e. "repeatability," would be expected to be 29 percent if the cow were bred to a different bull for each calving. If the cow were bred to the same sire each time this "repeatability" would be increased to 41 percent (full sib $r = 0.41$).

How the genotypes of the calf or the maternal characteristics affect the length of gestation is not known.

If it were desirable to change the length of gestation in cattle it should be possible to do so with such high heritability of gestation period. It is impossible to say how much change in the length of gestation could occur without affecting the survival of the fetus, which may in turn limit the modification possible in the length of gestation period.

Summary

The average length of 384 gestation periods was 278.2 days with a standard deviation of 4.8 days. Male calves were carried a significantly longer period of time than females. The order of calving had a significant effect in the female calves but not in the males. There was a positive correlation between the length of gestation period and the heart girth measurement. No effect of year and season of calving on the length of gestation was indicated. There was a highly significant positive correlation between the length of gestation and the birth weight of the calf. Neither the inbreeding of the dam nor the inbreeding of the calf had a significant effect.

The genotype of the calf was responsible for 48 percent of the total variance in sex adjusted records, of which 32 percent was due to the additive gene effects and 16 percent due to dominance deviations. The dam was responsible for 21 percent of the variance (six percent due to the additive gene effects and 15 percent due to permanent environmental causes and dominance deviations effective directly through the dam). Characteristics of the calf seemed about three times as important as the characteristics of the dam.

Literature Cited

Alexander, M. H. 1950. Length of Gestation in the Five Major Breeds of Dairy Cattle. Jour. Dairy Sci. (Abstract) 33: 377.

Carmichael, W. J. and J. B. Rice. 1920. Variations in Farrow with Special Reference to the Birth Weight of Pigs. Ill. Agr. Exp. Sta. Bul. 226.

Chapman, A. B. 1931. A Statistical Study of the Birth Weights of Lambs. M. S. Thesis, Iowa State College.

Copeland, L. 1930. Length of Gestation in Jersey Cows. Jour. Dairy Sci. 13: 257.

Kelley, R. B. 1943. The Length of Gestation Periods Preceding Single and Multiple Birtl s in Sheep. Austral. Vet. Jour. 19: 43.

Knapp, B., Jr., W. V. Lambert, and W. H. Black. 1940. Factors Influencing Length of Gestation and Birth Weight in Cattle. Jour. Agr. Res. 61: 277.

Knoop, C. E. and C. C. Hayden. Study of the Length of Gestation and Service Record of Dairy Cows. Ohio Agr. Exp. Sta. Bimo. Bull. 166.

Knott, J. C. 1932. A Study of the Gestation Period of Holstein-Friesian Cows. Jour. Dairy Sci. 15: 87.

Littlewood, R. W. 1937. Weight of Calves and Period of Gestation in Some Indian Breeds of Cattle. Agr. and Livestock in India 7: 61.

Lush, J. L., H. O. Hetzer, and C. C. Culbertson. 1934. Factors Affecting Birth Weights of Swine. Genetics 19: 329.

Phillips, R. 1928. Rate of Growth in Lambs. Welsh Jour. Agr. 4: 121.
Rife, D. C. 1948. Variations in the Length of Gestation in Aberdeen-Angus and Hereford Cows Carrying Purebred and Crossbred Calves. Abs. Book, 8th Int'l Gen. Congress 112–113.
Rife, D. C., P. Gerlaugh, L. Kunkle, G. W. Brandt, and L. H. Snyder. 1943. Comparative Lengths of the Gestation Periods of Aberdeen-Angus and Hereford Cows Carrying Purebred and Crossbred Calves. JOURNAL OF ANIMAL SCIENCE 2: 50.
Snedecor, G. W. and G. M. Cox. 1935. Disproportionate Subclass Numbers in Tables of Multiple Classification. Iowa Res. Bul. No. 180.
Terrill, C. E. and L. N. Hazel. 1947. Length of Gestation in Range Sheep. Am. Jour. Vet. Res. 8: 66.
Uppenborn, W. 1933. Untersuchungen über die Trächtigkeitsdauer der Stuten, mit einem Anhang: Untersuchungen über Zwillingsgeburten beim Pferd. Z. Zücht. 28: 1.
Wisnicky, W. and L. E. Casida. 1948. A Manual Method for the Diagnosis of Pregnancy in Cattle at an Early Stage of Gestation. J.A.V.M.A. 113: 451.
Wright, S. 1934. The Method of Path Coefficients. Ann. Math. Statis. 5: 161.
Wright, S. 1935. The Analysis of Variance and the Correlation between Relatives with Respect to Deviations from an Optimum. Jour. Genetics 30: 243.

THE EFFECT OF THE PLANE OF NUTRITION ON THE CARCASS QUALITY OF A LINE OF SWINE BASED ON A CHESTER WHITE AND DANISH LANDRACE CROSS[1]

H. H. Brugman

The State College of Washington

THE carcass quality of an animal is the result of the interaction of its genetic capabilities with its environment. The plane of nutrition on which the animal is raised constitutes a large part of the environmental effect.

McMeekan and Hammond (1940) found that different planes of nutrition, during different intervals in the development of swine, affected the type and quality of the carcass. They fed four groups of swine, using the same plane of nutrition in two successive periods for two groups and different planes in two successive periods for two other groups. The first group was H. H. (high-high) or full fed for the two periods. The second group was H.L. (high-low) or full fed and then limited fed. The third group was L.H. (low-high) or limited fed and then full fed. The fourth group was L.L. (low-low) or limited fed during both periods. They found that the different methods of feeding had an important effect on the type of carcass produced. In proportion of muscle and fat, the L.H. had the least muscle. The H.H. had a greater proportion of muscle than the L.H. and approached the L.H. in composition of muscle and fat. The L.L. had a minimum of fat but the lean was not well developed. The H.L. had the proportionately best developed muscle and a minimum of fat. Winters *et al.* (1949) found that swine fed a restricted diet throughout yielded the leanest carcass.

[1] Published as Scientific Paper No. 904 Agricultural Experiment Station, Institute of Agricultural Sciences, The State College of Washington. This is the first of a series of reports of a project entitled, "A Fundamental Study of the Relationship Between Nutrition and the Improvement of Animals for Meat Production Through Breeding." This study was conceived and initiated by Dr. E. J. Warwick in 1947 and was supported in part by grants from Swift & Co., Chicago, Illinois; American Dry Milk Institute, Inc., Chicago, Illinois; Carstens Packing Co., Tacoma and Spokane, Washington; Gibson Packing Company, Yakima, Washington; Hiram Walker, Peoria, Illinois, and Standard Brand, Inc., New York, New York.

The advisory committee to the project consists of: Dr. H. H. Brugman, Assistant Professor of Animal Husbandry, Assistant Animal Husbandman, The State College of Washington; Dr. M. E. Ensminger, Chairman of the Department of Animal Husbandry, The State College of Washington; Dr. S. P. Swenson, Dean of the College of Agriculture, The State College of Washington; Dr. H. E. Robinson, Assistant Director of Research, Swift & Co., Chicago, Illinois; Dr. R. T. Clark, National Coordinator Beef Cattle Research, Room 530, New Customhouse, Denver 2, Colorado; Dr. E. J. Warwick, Regional Coordinator S-10, Beef Cattle Breeding, 110 McCord Hall, University of Tennessee, Knoxville 16, Tenn.; Mr. W. F. Wilhelm, President of the Washington Swine Breeders Association, Rosalia, Washington.

Experimental

The data reported herein are from a study of the relationship between nutrition and the improvement of animals for meat production through breeding. The study was started in 1947 and will continue for seven generations or approximately 10 years.

The animals studied originated as crossbred animals from 5 groups of relatively unrelated Chester White gilts; each group consisted of 5 females and was bred to a different Danish Landrace boar. The litter of each female, at 8 weeks of age, was divided equally and at random and in this manner, two lines of swine were established which on the average are expected to be genetically similar. One line is on full feed (self-fed). The other line is on 70 percent of full feed (as determined by a growth curve which was established by a pilot trial). At 150 pounds the animals are indexed, taking into account fertility, survival, and rate of gain. The highest indexed animals are saved for breeding purposes. Animals not used as breeding stock are then full fed until they weigh approximately 220 pounds. In this manner a H.H. line (full fed for both periods) and a L.H. line (limited fed to 150 pounds, full fed from there on) were established. The carcass data for this study were gathered from these animals. Body measurements of the live animal at 150 pounds were taken.

The lines are closed to outside blood and the same system of matings is practiced in each line in order to keep the inbreeding coefficients as nearly alike as possible. No matings are closer than between quadruple second cousins. The compositions of the rations fed to each line are identical; and they appear to be adequate in all respects; the only difference is the level at which they are fed. The body measurements and carcass data of two generations are reported.

Results and Discussion

Body measurements at 150 pounds

Table 1 shows the average body measurements of the F_1 and F_2 animals when they reached approximately 150 pounds. There was no significant difference[2] in the body measurements between lines within generations.

The F_1 low-plane line required 56 days longer than the F_1 high-plane line and the F_2 low plane, 67 days longer than the F_2 high-plane line to reach 150 pounds. These differences are statistically highly significant.

Differences between years were not determined, since the measurements were made by different individuals in each generation but by the same men within years.

[2] Differences were tested for significance by the "t" test as described by Fisher (1946).

TABLE 1. BODY MEASUREMENTS OF THE F_1 AND F_2 ANIMALS AT 150 POUNDS

Comparison	F_1		F_2	
	High plane	Low plane	High plane	Low plane
Number	60	57	87	96
Live weight, lb.	152.9	153.5	150.3	148.6
Length, in.	45.7	47.5	39.0	41.9
Width of body at:				
Shoulder, in.	10.1	9.8	10.4	10.0
Loin, in.	8.5	8.4	9.3	7.9
Ham, in.	9.7	9.7	10.3	10.1
Depth of body, in.	11.9	11.8	12.7	11.6
Height of animal, in.	22.6	22.3	25.1	25.7
Days to reach 150 lb.	159±3	215±2	153±1	220±3

Carcass measurements at approximately 220 pounds live weight

The animals were slaughtered at approximately 220 pounds live weight. Table 2 shows the carcass comparison of the F_1 H.H. and L.H. animals.

There was no difference between the chilled weights of the two lines. The L.H. line had less total lard than the H.H. line. Body length and loin showed no differences.

TABLE 2. CARCASS COMPARISON OF THE F_1 H.H. AND L.H. ANIMALS[1]

Comparison	H.H.	L.H.	Difference
Number	12	13	
Chilled Weight, lb.	155.30±1.92	153.19±2.27	2.11
Average Back Fat, in.	1.30±0.05	1.14±0.04	0.16**
Body Length, in.	30.33±0.28	30.51±0.16	0.18
Length Hind Leg, in.	21.01±0.71	23.06±0.08	2.05**
Hams (trimmed), lb.	29.20±0.45	30.73±0.75	1.53**
Loin (trimmed), lb.	25.75±0.75	26.00±0.74	0.25
Bellies (trimmed), lb.	21.48±1.09	16.93±1.08	4.55**
Picnics (trimmed), lb.	16.30±0.39	19.94±0.89	3.64**
Boston Butts (trimmed), lb.	9.76±0.22	10.36±0.22	0.60**
% Primal Cuts	64.86±0.22	68.12±0.59	3.26**
Jowls, lb.	4.29±0.18	3.26±0.18	1.03**
Back Fat, lb.	11.14±0.78	8.38±0.64	2.76**
Leaf Lard, lb.	4.88±0.47	3.77±0.19	1.11
Plate Lard, lb.	3.81±0.21	3.24±0.17	0.57**
Total Lard, lb.	19.83±1.24	15.35±0.96	4.48**
Trim, lb.	27.98±1.04	29.61±1.45	1.63*

[1] The carcasses were cut in the WSC Meats Laboratory under the supervision of Mr. E. A. Kline.

*P = .01-.05.

**P = <.01.

The length of hind leg of the L.H. animals was greater than the length of hind leg in the H.H. line. However, the L.H. yielded more ham than the H. H. Ensminger and Brugman (1950) found a high correlation between length of hind leg and ham yield.

Although the average yield of leaf lard in the L.H. was almost 20 percent less than the H.H., the variation was so great in each line (H.H. range 2.5–7.63 lbs., L.H. range 2.38–5.94 lbs.) that there was no significant difference between the lines. The L.H. yielded a higher percentage of total trimmed

TABLE 3. CARCASS COMPARISON OF THE F_2 H.H. AND L.H. ANIMALS[1]

Comparison	H.H.	L.H.	Difference
Number	35	23	
Chilled Weight	149.6±2.0	152.8±1.8	3.2
Average Back Fat, in.	1.6±0.5	1.3±0.03	0.3**
Body Length, in.	31.1±0.6	31.7±0.2	0.6
Hams (trimmed), lb.	31.8±1.0	34.0±0.2	2.2**
Loin (trimmed), lb.	24.2±0.5	26.0±0.4	1.8**
Bellies (trimmed) lb.	24.1±0.5	25.5±0.5	1.4*
Picnics (trimmed), lb.	14.7±0.3	16.4±0.3	1.7**
Boston Butts (trimmed), lb.	11.4±0.3	11.7±0.3	0.3
% Primal Cuts	71.1	74.0	2.9**
Jowls, lb.	5.2±0.1	4.6±0.1	0.6**
Back Fat, lb.	11.5±0.5	8.6±0.1	2.9**
Leaf Lard, lb.	4.5±0.2	3.6±0.1	0.9**
Plate Lard, lb.	3.2±0.1	2.9±0.1	0.3
Total Lard, lb.	19.1±0.6	15.2±0.6	3.9**
Trim, lb.	19.0±0.9	16.3±0.3	2.7**

[1] The killing and cutting of these animals were done through the courtesy of Carstens Packing Company in their Spokane plant.

* P=0.01–0.05.

** P= <0.01.

primal cuts, less jowl, and less total lard. The L.H. yielded less trimmed belly than the H.H.

Table 3 shows the carcass comparison of the F_2 H.H. and L.H. animals. There was no significant difference between chilled weights in the two lines. The yield of fat cuts in the L.H. was significantly less in all comparisons except the plate lard, in which the difference was in the same direction. The L.H. yielded a greater percentage of total trimmed primal cuts (hams, loins, bellies, picnics and Boston butts). The yield of trimmed bellies from the L.H. was slightly higher ($P = < .05$).

The Boston butt was the only primal cut which did not differ between lines. Length of body of the animals in the two lines did not show a difference. The L.H. yielded less trim. From these data it appears that muscle

tissue is laid down first, and that additional feed deposits more fat. However, full feeding the Low plane line after it reached 150 pounds did not increase the fat deposition sufficiently to bring it to the same level as the High plane line full fed for the entire period.

Some of the differences in yield of belly, Boston butts, trim, and loins between generations are probably due to differences in cutting practices. The percentage of total trimmed primal cuts and fat cuts is probably a better criterion for comparison between generations than the individual primal cuts.

Because the F_1 and F_2 carcasses were cut by different individuals, chilled weight, body length, and average backfat (inches) are the only factors between generations which should be compared. Table 4 shows these F_1 and F_2 comparisons.

TABLE 4. CARCASS COMPARISON OF THE F_1 AND F_2 H.H. AND L.H. ANIMALS

Comparison	F_1 H.H.	F_2 H.H.	Difference	F_1 L.H.	F_2 L.H.	Difference
Number	12	35		13	23	
Chilled Weight, lb.	155.3±1.9	149.6±2.0	5.7	153.2±1.6	152.8±1.8	0.4
Body Length, in.	30.3±0.3	31.1±0.6	0.8*	30.5±0.1	31.7±0.2	1.2**
Average Thickness of Backfact, in.	1.3±0.05	1.6±0.05	0.3	1.1±0.03	1.3±0.03	0.2*

* P = 0.01–0.05.
** P = <0.01.

There was no difference in chilled weights between lines nor between generations. The body length of the F_2 H.H. was greater ($P = <.05$) than the F_1 H.H. There was no difference in thickness of backfat in the H.H. between generations. The body length of the F_2 L.H. was significantly greater than the F_1 L.H. and the average backfat of the F_2 L.H. was greater ($P = <.05$) than of the F_1 L.H. Some of these generation to generation differences may be due indirectly to factors considered in selection of the breeding stock.

Summary

Limiting the feed intake of swine to 70 percent of full feed until the animals reach 150 pounds, did not affect the body measurements at that weight. The number of days required to reach 150 pounds was significantly greater between levels of feeding within generations.

The carcass qualities of swine can be changed by limiting the feed intake to 70 percent of full feed up to 150 pounds and full feeding from then on until the animal reaches approximately 220 pounds live weight, as indicated

by a significantly higher percentage of the total five trimmed primal cuts and lower percentage of total lard produced by the L.H. line. The L.H. produced a leaner carcass.

The F_2 H.H. had a longer carcass than the F_1 H.H. but did not differ in average thickness of backfat from it. The F_2 L.H. also had a longer carcass and the average thickness of backfat was slightly greater than the F_1 H.H.

Literature Cited

Ensminger, M. E. and H. H. Brugman. 1950. A Genealogy and Carcass Study of the W.S.C. Project No. 61 Hog. State College of Washington Agric. Expt. Station Technical Bulletin.

Fisher, R. A. 1946. Statistical Methods for Research Workers. 10th Edition. Oliver and Boyd, Edinburgh, Publishers.

McMeekan, C. P. and John Hammond. 1940. The Relation of Environmental Condition to Breeding and Selection for Commercial Types in Pigs. Empire Jour. of Exp. Agric. 8: 6.

Winters, L. M., C. F. Sierk and J. N. Cummings. 1949. The Effect of Plane of Nutrition on the Economy of Production and Carcass Quality of Swine. JOURNAL OF ANIMAL SCIENCE 8: 132.

DRIED WHOLE AUREOMYCIN MASH AND MEAT AND BONE SCRAPS FOR GROWING-FATTENING SWINE

K. C. Lepley, D. V. Catron and C. C. Culbertson[1,2]

Iowa State College[3]

SINCE the isolation of vitamin B_{12} by Rickes *et al.* (1948) and Smith (1948), many investigations have been undertaken to determine the value of crude vitamin B_{12} concentrates and APF concentrates in swine nutrition. In most of the research, the microbially fermented concentrates have been added to all-plant rations. Very few investigators have used a source of natural animal protein in their basal rations.

Burnside and co-workers (1949) added an APF supplement (Lederle) to a corn-fish meal ration and obtained an increase in gain. Anderson and Hogan (1949) found that the addition of a crude vitamin B_{12} concentrate to a ration containing digester tankage when fed to smaller pigs produced faster gains than the same ration without the vitamin B_{12} concentrate fed to larger pigs.

The addition of antibiotics to swine rations is a new venture in the field of nutrition. Jukes *et al.* (1950) reported that the addition of aureomycin and vitamin B_{12} to weanling pig rations produced greater gains than the addition of vitamin B_{12} alone. Luecke, McMillen and Thorpe (1950) found that streptomycin plus crystalline vitamin B_{12} produced as rapid gains as an APF supplement (Lederle).

The experimental work reported in this paper is the first work done at this station with an APF concentrate known to contain an antibiotic, namely aureomycin.

Previous work at this station by Catron and Culbertson (1949), had indicated that crude vitamin B_{12} and APF concentrates could supply vitamin B_{12} and unidentified growth factors as efficiently as animal proteins. Most research reported to date has been conducted to determine if all of the animal protein could be replaced with vegetable protein and an APF produced by microbiological fermentation. The tests reported herein were conducted to determine how much of the animal protein, if any, could be replaced with soybean oil meal and an APF concentrate.

Journal Paper No. J-1803, of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 930.

[1] The authors wish to acknowledge the assistance of Prof. Paul Homeyer and Helen Maddock in the statistical analysis of the data.

[2] The authors wish to express their appreciation of Lederle Laboratories Div., American Cyanamid Co., Pearl River, New York and Dr. T. H. Jukes for furnishing the B-vitamins and APF (dried whole aureomycin mash) used in these experiments.

[3] Animal Husbandry Department, Ames, Iowa. Acknowledgment is gratefully made to Don Quinn, Animal Nutrition Farm foreman, and his associates for their assistance.

Experimental Procedure

Experiment 1

The primary objective of this experiment was to determine the supplementary value of APF (dried whole unextracted aureomycin mash) without meat and bone scraps and with two levels of meat and bone scraps, for growing-fattening pigs in concrete drylot. The second objective was to compare a ration containing 5% meat and bone scraps to a ration in which the latter was replaced with additional soybean oil meal and dried whole aureomycin mash on good alfalfa pasture.

Seven lots of six Duroc pigs were fed. The pigs on the first five treatments were in concrete drylot and those in the last two were on good alfalfa pasture. These pigs were produced by sows which had received rations containing 10% meat and bone scraps and 10% dehydrated alfalfa meal during gestation but neither during lactation. This procedure was followed in order to produce pigs partially depleted of vitamin B_{12} at weaning.

Allotment of the animals was made on two different dates since farrowing was spread out and all pigs were not available at the same time. An attempt was made to have the same number of "excellent," "good," and "medium"

TABLE 1. RATION COMPOSITION—EXPERIMENTS 1 AND 2

Lot number	I	II	III	IV	V	VI	VII
Treatment	Basal	Basal incl. 5% meat & bone scraps	Basal incl. 5% meat & bone scraps+ 0.25% APF	Basal Incl. 2½% meat & bone scraps	Basal incl. 0.25% APF	Basal incl. 5% meat & bone scraps on pasture	Basal incl. 0.25% APF on pasture
Ingredients (%)							
Gr. Yellow Corn	69.0	67.5	67.5	66.0	69.0	75.5	73.5
Exp. Soybean Oil Meal	23.0	16.5	16.5	20.0	23.0	16.0	22.0
Dehy. Alfalfa Meal	5.0	5.0	5.0	5.0	5.0	—	—
Vitamin D_3 Premix[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin A Premix[2]	1.0	1.0	1.0	1.0	1.0	—	—
B-vitamin Premix[3]	2.0	2.0	2.0	2.0	2.0	—	—
Gr. Limestone	0.5	0.4	0.15	0.65	0.65	0.9	1.0
St. Bonemeal	0.9	—	—	—	0.5	—	0.65
Iodized Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Trace Mineral Premix[4]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Meat and Bone Scraps	—	5.0	5.0	2.5	—	5.0	—
APF (Dried Whole Aureomycin Mash)	—	—	0.25	0.25	0.25	—	0.25

[1] Contained 20,000 USP units per pound of premix.

[2] Contained 181,000 I. U.per pound pound of premix.

[3] Contained 370 mg. calcium pantothenate; 25 gms. choline; 25 mg. folic acid; 250 mg. niacin; 60 mg. pyridoxine; 70 mg. riboflavin and 50 mg. thiamin per pound of premix.

[4] Contained Fe, Cu, Co, Mn, Zn and K with a Ca carrier.

pigs on each treatment. Selection and allotment was made on the basis of litter, weight, condition, age and sex.

Beginning drylot rations (table 1) were calculated to contain 18% protein. The protein level was lowered to 15% when the pigs in each lot averaged 75 pounds; it was lowered again, to 12% protein at an average weight of 150 pounds. Pasture rations started at 16% protein until an average pig weight per lot of 75 pounds was reached, and was 13% from 75 to 150 pounds and 10% from 150 pounds to market weight. The protein levels were lowered by increasing the corn and decreasing the soybean oil meal content of the ration. All rations were self-fed and automatic water fountains were used.

The drylot pigs were housed in a hollow-tile building. They were confined to indoor pens for the duration of the experiment. Sun shades were provided for those on pasture. During the fall months the shades were closed.

One pig died in Lot II. Post mortem revealed a hemorrhagic gastritis, severe catarrhal enteritis and nephritis. Cultures prepared from the various organs failed to reveal any pathological bacteria.

Experiment 2

The five lots in this experiment were identical with the drylot treatments in Experiment 1; this experiment was set up to serve as a check on Experiment 1.

The primary purpose was to determine the supplemental value of dried whole unextracted aureomycin mash without meat and bone scraps and with two levels of meat and bone scraps.

The pigs used in this experiment were from two sources. Half of them were considered semi-depleted of vitamin B_{12} when the experiment started. The other half of the pigs were from sows which had received what were considered adequate gestation and lactation rations. Part of the semi-depleted pigs were from sows which had received an all-plant ration composed of corn, soybean oil meal, vitamin D_2, ground limestone, steamed bonemeal and salt from two months prior to breeding up through weaning. One litter was from a sow which had received 10% meat and bone scraps and 10% dehydrated alfalfa meal in the gestation ration but both were removed from the lactation ration. A secondary purpose was to determine if there was a difference in growth response to APF between semi-depleted and non-depleted pigs.

The non-depleted pigs were produced by sows which had received a ration containing ground yellow corn, soybean oil meal, condensed red fish solubles, meat and bone scraps, dehydrated alfalfa meal, vitamin D_2, riboflavin and a complete mineral mix which included trace minerals. This ration was fed from two months prior to breeding up through weaning.

Eight Duroc pigs were allotted to each treatment. Allotments were made, on three consecutive Tuesdays, as the pigs were weaned. At least one pig from each litter was allotted to each treatment. Six litters were involved. Allotment was made on the basis of litter, weight, condition, age and sex.

The pigs were confined to an outside concrete feeding floor with a shed-type enclosure on the west. Solid wooden partitions were supplied to prevent fecal and urinal contamination between treatments.

The rations in this experiment were identical with those in the drylot portion of Experiment 1 and are presented in Table 1. The same feeding and management practices prevailed in both experiments.

Three pigs were removed from the basal ration after four weeks on experiment. They had severe diarrhea and had not responded to medication with an arsenical drug. At removal, they were very weak, thin and emaciated and had either lost or just maintained weight over the four week period. One pig was removed from Lot V because of rupture.

The data in table 2 were analyzed statistically according to methods of Snedecor (1946).

Results and Discussion

The addition of dried whole aureomycin mash either with or without the addition of meat and bone scraps increased average daily gains significantly (table 2). The addition of meat and bone scraps did not significantly improve the rations.

When 5% meat and bone scraps was replaced with additional soybean oil meal and 0.25% dried whole aureomycin mash on good alfalfa pasture, the average daily gain was increased significantly. Apparently, neither the meat and bone scraps or the good alfalfa pasture supplied qualitatively or quantitatively the vitamin B_{12}, aureomycin and/or other unidentified factors contained in the dried whole aureomycin mash. This result tends to support the work of Zucker and Zucker (1948) who reported no animal protein factor activity in alfalfa meal or green growing grass. However, the average daily gains of the pigs in Lot VII (APF fed on pasture) was significantly greater than the gains of the pigs in Lot V (APF fed in drylot). This would indicate that the alfalfa pasture furnished nutrients not supplied by the basal ration or whole dried aureomycin mash.

In the data found in table 3, the addition of dried whole aureomycin mash either with or without the addition of meat and bone scraps increased average daily gain significantly. The addition of only meat and bone scraps increased the average daily gain significantly. There was no interaction between the effect of meat and bone scraps and APF; additive effects were obtained.

When the data from two experiments were combined and analyzed, the

TABLE 2. RESULTS OF EXPERIMENT 1. SUMMER 1949

Lot	Treatment[1]	Av. final weight[2] lbs.	Av. daily gain,[3] lbs.	Av. daily feed, lbs.	Feed per 100 lbs. gain, lbs.
Drylot:					
I	Basal Ration	199	1.36	4.61	339
II	Basal Incl. 5%Meat and Bone Scraps	209	1.38	5.11	371
III	Basal Incl. 5% Meat and Bone Scraps+0.25% APF	200	1.56	5.25	337
IV	Basal Incl. 2.5% Meat and Bone Scraps+0.25% APF	204	1.61	5.25	327
V	Basal Incl. 0.25% APF	199	1.53	4.95	323
Pasture:					
VI	Basal Incl. 5% Meat and Bone Scraps	199	1.40	4.46	320[4]
VII	Basal Incl. 0.25% APF	213	1.80	5.28	294[4]

[1] Six pigs started 6–3–49 to 6–24–49. One removed from Lot II, not nutritional.

[2] Average initial weight per lot: 22.6 ± 0.2 pounds.

[3] The addition of APF significantly increased average daily gain with or without the addition of meat and bone scraps at P = .05. The differences in gains between Lot V and Lot VII and between VI and VII are significant at P = .01.

[4] Represents experimental rations consumed and does not include pasture eaten.

addition of APF increased average daily gains significantly. The addition of meat and bone scraps did not produce significant increases in daily gain over the basal ration.

These results are similar to those obtained by Burnside *et al.* (1949).

TABLE 3. RESULTS OF EXPERIMENT 2. SUMMER 1949—CONCRETE DRYLOT

Lot	Treatment[1]	Av. final weight,[2] lbs.	Av. daily gain,[3] lbs.	Av. daily feed, lbs.	Feed per 100 lbs. gain, lbs.
I	Basal Ration	200	1.25	4.56	365
II	Basal Incl. 5% Meat and Bone Scraps	203	1.45	4.96	343
III	Basal Incl. 5% Meat and Bone Scraps+0.25% APF	200	1.72	5.99	350
IV	Basal Incl. 2.50% Meat and Bone Scraps+0.25% APF	205	1.66	5.37	324
V	Basal Incl. 0.25% APF	204	1.59	5.79	365

[1] Eight pigs per lot started 7–26–49 to 8–9–49. Three removed from Lot I, one from Lot V.

[2] Average initial weight 25.4 ± 0.3 pounds per lot.

[3] The addition of meat and bone scraps increased gains significantly at P = .05. The addition of APF increased gains significantly at P = .01. No interaction occurred between effect due to APF and meat and bone scraps.

They obtained an increase in daily gain by the addition of an APF supplement (Lederle) to a corn-fish meal ration for weanling pigs. Anderson and Hogan (1949) were able to increase gains by the addition of crude vitamin B_{12} concentrate (Merck) to a corn-soybean oil meal ration containing 5% digester tankage.

About 90% of the increased gain obtained by the addition of APF or meat and bone scraps was found to be due to the increased quantity of feed eaten. Only about 10% of the increased gain was due to the quality of feed.

In Experiment 2, no differences in growth rate were obtained that could be attributed to previous treatment. Those pigs from sows on all-plant protein lactation rations gained just as rapidly as those from sows fed rations including sources of animal protein. Apparently depletion was not a factor in producing differences in daily gains in this experiment.

In both experiments, diarrhea was noticed in all lots of pigs not receiving the dried whole, unextracted aureomycin mash. Some pigs fed both the basal ration and the basal plus 5% meat and bone scraps, in both drylot and pasture, had diarrhea. In Experiment 1, diarrhea was largely confined to those pigs added in the second allotment.

The absence of diarrhea and subsequent more rapid gains in the pigs fed the whole dried aureomycin mash has since been attributed to the presence of aureomycin or unidentified nutritional factors. Jukes *et al.* (1950) reported that the addition of aureomycin or APF supplement to corn-peanut meal rations prevented dirrrhea. Those groups receiving vitamin B_{12}, but not aureomycin or the APF supplement, had some diarrhea.

The basal ration pigs displayed unusual symptoms of irritability. Those pigs which were fed the dried whole unextracted aureomycin mash were more uniform in hair color and finish throughout the growing-fattening period.

Summary

To a corn-soybean oil meal ration, fortified with B-vitamins, vitamin A, vitamin D_2 and minerals including trace minerals, was added dried whole aureomycin mash without meat and bone scraps and with two levels of meat and bone scraps. The drylot treatments were replicated in a second experiment.

The addition of the dried whole aureomycin mash increased average daily gains significantly in both drylot and pasture. The increased gains were obtained regardless of the presence of meat and bone scraps in the ration. Pigs fed the dried whole aureomycin mash were more uniform in hair color and finish.

The addition of meat and bone scraps did not significantly increase gains

in either experiment. There was no interaction between the effects due to dried whole aureomycin mash and meat and bone scraps.

Either aureomycin or other nutritional factors present in the APF (dried whole unextracted aureomeycin mash) helped control diarrhea. No diarrhea occurred in the pigs which were fed APF in their rations. Some pigs had diarrhea in all of the lots not receiving the dried whole aureomycin mash.

No significent difference in daily gains was obtained between the depleted and non-depleted pigs.

Literature Cited

Anderson, G. C. and A. G. Hogan. 1949. A Deficiency of Vitamin B_{12} in a Practical Ration for Weanling Pigs. JOURNAL OF ANIMAL SCIENCE 8: 614.

Burnside, J. E., T. J. Cunha, A. M. Pearson, R. S. Glasscock and A. L. Shealy. 1949. Effect of APF Supplement on Pigs Fed Different Protein Supplements. Arch. Biochem. 23: 328.

Catron, Damon and C. C. Culbertson. 1949. Faster Gains with APF. Iowa Farm Science 3: 3.

Jukes, T. H., E. L. R. Stokstad, R. R. Taylor, T. J. Cunha, H. M. Edwards and G. B. Meadows. 1950. Growth-Promoting Effect of Aureomycin on Pigs. Arch. Biochem. 26: 324.

Luecke, R. W., W. N. McMillen and F. Thorpe, Jr. 1950. The Effect of Vitamin B_{12}, Animal Protein Factors and Streptomycin on the Growth of Young Pigs. Arch. Biochem. 26: 326.

Rickes, E. L., N. G. Brink, F. R. Koniuszy, T. R. Wood and K. Folkers. 1948. Crystalline Vitamin B_{12}. Science 107: 396.

Smith, E. L. 1948. Purification of Anti-pernicious Anemia Factors from Liver. Nature 161: 638.

Snedecor, G. W. 1946. Statistical Methods Applied to Experiments in Agriculture and Biology. The Iowa State College Press, Ames, Iowa.

Zucker, L. M. and T. F. Zucker. 1948. Does "Animal Protein Factor" Occur in Green Plants? Proc. Soc. Exp. Biol. Med. 68: 432.

EFFECT OF APF SUPPLEMENT ON EFFICIENCY OF FEED UTILIZATION FOR THE PIG

T. J. Cunha, J. E. Burnside, G. B. Meadows, H. M. Edwards, R. H. Benson, A. M. Pearson and R. S. Glasscock

University of Florida[1]

EXPERIMENTAL work by Cunha *et al.* (1949) with a corn-peanut meal ration showed that the responses in pigs produced by an aureomycin fermentation product designated APF (Lederle) are different from those produced by vitamin B_{12}. Using the same corn-peanut meal ration, Burnside *et al.* (1949) showed that the Lederle APF increased the feeding value of peanut meal and soybean oil meal so that these values were similar to the feeding value of the fish meal (30% of whole menhaden fish meal in the ration) used. Cunha *et al.* (1949) found that the Lederle APF spared the methionine needs of the pig and that the Lederle APF contained B_{12} plus some other factor(s). These later data are in agreement with those of Stokstad *et al.* (1949) who showed that the same APF supplement contained some unidentified factor in addition to B_{12} for the chick. Cunha *et al.* (1950) showed that the Lederle APF is concerned with efficiency of protein utilization and stated that protein requirements of swine may need to be re-evaluated by using adequate amounts of the factors present in the Lederle APF in the ration. The above studies culminated in the finding by Jukes *et al.* (1950) that aureomycin which is present in APF, increased growth in the pig. Thus it was demonstrated that the growth response of pigs which were fed APF supplement was partially due to aureomycin, which APF contains in addition to B_{12} and possibly other factors. The findings of Jukes *et al.* (1950) and those of Burnside *et al.* (1950) showed that aureomycin and the Lederle APF supplement were effective in preventing scours with the pig.

The experiments reported herein were undertaken to determine the effect of APF on efficiency of feed utilization. A summary of 12 experiments is reported in this paper.

Materials and Methods

Pigs, with varying initial weights of 18 to 48 pounds, were used. They were selected and distributed equally in each lot with respect to initial weight, sex, age, condition, thriftiness and previous dietary history. The pigs were fed in dry lot on concrete floors which were washed once daily.

[1] Department of Animal Husbandry and Nutrition, Florida Agricultural Experiment Station, Gainesville, Florida, Acknowledgment is made to the following persons for assistance during various phases of these trials: D. M. Buschman, H. H. Hopper, G. A. LaMar, C. B. Shawver, R. F. Sewell and S. J. Folks.

TABLE 1. EFFECT OF APF ON RATE OF GAIN, EFFICIENCY ON FEED UTILIZATION AND HEMOGLOBIN LEVEL

Exp. No.	Lot No. of APF fed	Aureomycin content per lb. of APF, grams	B_{12} content per lb. of APF, mgs.	Level of dry APF in the ration, percent	Days on experiment	Wt. of pigs at beginning of experiment lbs.	Av. daily gain on Basal, lbs.	Av. daily gain on Basal+ APF, lbs.	Difference in av. daily gain, lbs.	Feed required per 100 lbs. gain on Basal, lbs.	Feed required per 100 lbs. gain on Basal+ APF,[4] lbs.	Difference in feed required per 100 lbs. gain	Hb. level on the Basal, at end of trial	Hb. level on the Basal+ APF, at end of trial
1	N195 and N199B	4.0 3.8	about 2	1.1	42	33	1.14	1.44	0.30	559	345	214	—	—
2	N195 and N199B	4.0 3.8	about 2	2.2	35	18	0.29	0.73	0.44	425	334	91	13.7	15.2
3	N203B	3.8	about 2	2.2	37	27	0.62	1.42	0.80	369	228	141	10.9	12.3
4	N203B	3.8	about 2	2.2	42	20	0.52	1.44	0.62	429	239	190	9.8	11.0
5	N203B and 8108–109	3.8 1.4	about 2	2.2	42	19	0.79	1.21	0.42	285	269	16	11.4	12.9
6	8108–109	1.4	about 2	2.2	40	19	0.75	1.25	0.50	285	261	24	—	—
7	8108–109	1.4	about 2	1.0	37	35	0.77	1.36	0.59	439[3]	276	153	—	—
8	8108–109	1.4	about 2	1.0	54	35	0.75	1.46	0.71	468[3]	281	187	10.7	12.0
9	8108–109	1.4	about 2	1.0	62	36	1.01	1.67	0.66	325[3]	305	20	11.5	12.75
10	8108–109	1.4	about 2	0.5	37	22	0.47	1.19	0.72	393	268	125	—	—
11	C-371	1.2	0.8[2]	1	59	48	0.79	1.72	0.93	446	307	139	—	—
12	C-371	1.2	0.8[2]	1	87	48	0.70	1.74	1.04	507	322	185	9.7	13.8
Average					47.8	30.0	0.72	1.39	0.64	410	286	124		

[1] Liquid APF, C-371 used at a level of 33 ml. per kilo of diet.

[2] Microbiological assay. All other APF preparations were assayed for B [2] with the chick. Assays conducted by Lederle Laboratories on B_{12} and aureomycin content of various APF supplements. Lot 8108–109 was a commercial batch of Animal Protein Factor Supplement; whereas, the others were experimental batches.

[3] B_{12} included in Basal. B_{12} not included other Basal lots.

[4] All APF preparations were obtained from Dr. T. H. Jukes, Lederle Laboratories, Pearl River, N.Y.

The various mixed rations were self-fed to the pigs in all lots. Four to five pigs were fed in each lot of the 12 experiments.

The basal ration used in experiments 1 through 6 consisted of ground yellow corn 57, peanut meal (hydraulic) 41.5, bone meal 0.5, limestone 0.5 and salt 0.5 percent. In experiments 7 through 12, the same basal ration was used except that instead of 0.5 percent salt, a level of 0.53 percent of a salt-trace mineral mixture (iodized salt 50 pounds, manganese sulfate 921 grams, ferrous sulfate 398 grams, copper sulfate 125 grams and cobalt carbonate 10 grams) was used.

Results and Discussion

The data in table 1 definitely show that APF is concerned with increasing the rate of gain. Supplementation with APF resulted in a marked increase in average daily gain above the basal ration, ranging from a minimum of 0.30 pound in experiment 1 to a maximum of 1.04 pounds difference daily in experiment 12. The variations in the rate of gain were at least partially associated with the degree of depletion of the pigs at the beginning of the experiment. This is borne out by the observation that pigs, which were fed the basal ration in order to deplete them before beginning the experiment, made slower gains than pigs which were started on experiment without undergoing the depletion period.

The data obtained on the feed required per 100 pounds of gain show that APF influences the efficiency of feed utilization. In every experiment the supplementation of the basal ration with APF resulted in a saving of feed as compared to the basal ration. The average saving of feed was 124 pounds per 100 pounds of gain in all experiments, ranging from approximately 16 pounds in experiment 5 to 190 pounds for experiment 4. Since the efficiency of feed utilization did not appear to be closely related to rate of gain, it would tend to indicate that some factor(s) other than the B_{12} or aureomycin content of the APF was responsible for the differences obtained in efficiency of feed utilization on the different trials. It is possible that individual variation as to requirements, storage or absence of storage in the animals at the beginning of the experiment, or the possible presence of another factor(s) in addition to B_{12} and aureomycin in the APF supplement may have accounted for the differences in feed utilization. Since Luecke *et al.* (1950) found no difference in feed utilization between pigs receiving a supplement of APF and those on a basal corn-soybean oil meal ration, it is probable that the corn-peanut meal ration contains a lower level of the deficient factor(s).

The data in table 1 indicate that APF supplementation increases the hemoglobin level of the pig. The increase in hemoglobin was more pronounced in experiment 12, which lasted for 87 days. Possibly APF supplementation

causes only a slight increase in the level of hemoglobin during short trials, but with longer experiments the increase becomes more pronounced.

In order to determine whether or not APF supplementation would be applicable from approximate weaning to market weights, the pigs on experiment 12 were fed throughout the growing-fattening period (from 48 to 199 pounds in weight). In this trial the pigs fed APF gained an average of 1.04 pounds more per day and required 185 pounds less feed per hundred pounds gain than those on the basal ration. Thus, this trial indicates that APF was beneficial for the pig throughout the growing-fattening period insofar as both rate of gain and efficiency of feed utilization are concerned.

Data by Jukes *et al.* (1950) showed that aureomycin increased the rate of gain of pigs fed a corn-peanut meal ration similar to that used in these trials. The increase in the rate of gain was almost equal to that obtained when the Lederle APF supplement was fed. Data by Cunha *et al.* (1950) showed that aureomycin supplementation was about as effective as the Lederle APF supplement in increasing efficiency of feed utilization and hemoglobin level. Thus it seems that the aureomycin in the Lederle APF is responsible for a good deal of the effect of APF in stimulating growth, increasing efficiency of feed utilization and the blood level of hemoglobin.

Summary

An average of 12 experiments definitely indicates that APF (Lederle) is concerned with efficiency of feed utilization. APF also increases the rate of gain and hemoglobin level of pigs fed the basal ration studied.

Literature Cited

Burnside, J. E., T. J. Cunha, H. M. Edwards, G. B. Meadows, G. A. LaMar, A. M. Pearson and R. S. Glasscock. 1950. Response of the Pig to APF, B_{12} and B_{12b}. Proc. Soc. Exp. Biol. and Med. 74: 173.

Burnside, J. E., T. J. Cunha, A. M. Pearson, R. S. Glasscock and A. L. Shealy. 1949. Effect of APF Supplements on Pigs Fed Different Protein Supplements. Arch Biochem. 23: 328.

Cunha, T. J., J. E. Burnside, D. M. Buschman, R. S. Glasscock, A. M. Pearson and A. L. Shealy. 1949. Effect of Vitamin B_{12}, Animal Protein Factor and Soil for Pig Growth. Arch. Biochem. 23: 324.

Cunha, T. J. H. H. Hopper, J. E. Burnside, A. M. Pearson, R. S. Glasscock and A. L. Shealy. 1949. Effect of Vitamin B_{12} and APF Supplement on Methionine Needs of the Pig. Arch. Biochem. 23: 510.

Cunha, T. J., J. E. Burnside, H. M. Edwards, G. B. Meadows, R. H. Benson, A. M. Pearson and R. S. Glasscock. 1950. Effect of Animal Protein Factor on Lowering Protein Needs of the Pig. Arch. Biochem. 25: 455.

Cunha, T. J., H. M. Edwards and G. B. Meadows. 1950. Unpublished data. Fla. Agr. Exp. Station.

Jukes, T. H., E. L. R. Stokstad, R. R. Taylor, T. J. Cunha, H. M. Edwards and G. B. Meadows. 1950. Growth Promoting Effects of Aureomycin on Pigs. Arch Biochem. 26: 324.

Luecke, R. W., W. N. McNillen and F. Thorp, Jr. 1950. The Effect of Vitamin B_{12}, Animal Protein Factor and Streptomycin on the Growth of Young Pigs. Arch. Biochem. 26: 326.

Stokstad, E. L. R., T. H. Jukes, J. Pierce, A. C. Page, Jr. and A. L. Franklin. 1949. The Multiple Nature of the Animal Protein Factor. Jour. Biol. Chem. 180: 647.

INADEQUACY OF PURIFIED DIETS FOR REPRODUCTION BY SWINE WITH OBSERVATIONS ON AN ADDED DEFICIENCY OF PANTOTHENIC ACID[1,2]

H. W. Hodgskiss, M. E. Ensminger, R. W. Colby[3] and T. J. Cunha[4]
State College of Washington

THE effects of a pantothenic acid deficiency in young growing pigs has been well established by Hughes (1938), (1939), (1942); Chick (1938); Wintrobe *et al.* (1939), (1942), (1943); Hughes and Ittner (1942); Follis and Wintrobe (1945) and Colby *et al.* (1948). However, within the knowledge of the authors, no work has been conducted concerning pantothenic acid deficiency in brood sows during the reproduction and lactation periods.

In addition to the work listed above, Ellis *et al.* (1943) described the value of pantothenic acid and pyridoxine, when added to swine rations, in the prevention of the development of locomotor incoordination resulting from nerve degeneration. They suggested that the rather frequent occurrence of this condition in growing swine fed natural rations appeared to be due to a borderline level of pantothenic acid present. McMillen *et al.* (1948) produced a pantothenic acid deficiency, characterized by goose-stepping with the hind legs, in pasture-raised pigs fed a partial natural ration for seven weeks. Such results would indicate that some of the natural rations commonly used for swine feeding may be low or borderline in their content of pantothenic acid. Such borderline deficiencies may be a contributing factor toward the high incidence of small pig losses.

The work herein reported was undertaken to obtain additional data on reproduction by sows consuming purified rations, and to study the effect of an added pantothenic acid deficiency.

Materials and Methods

Six Landrace-Chester White crossbred gilts were used in this study. The gilts were divided into two lots of three each. Prior to being placed on the purified ration, all of the gilts were maintained upon the regular herd ration used at this station. This ration consisted of alfalfa meal, 20 percent; tank-

[1] Published as Scientific Paper No. 862, Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington, Pullman, Washington.

[2] This work was made possible through grants from the Research Corporation, New York City, and from Armour and Company, Chicago. We are indebted to Dr. D. F. Green and Merck & Company, Rahway, New Jersey for supplying the crystalline B-vitamins. The cooperation of Dr. T. H. Jukes and Lederle Laboratories, Rockefeller Plaza, New York, in supplying folic acid is gratefully appreciated. The vitamin A and D oil (Oladal) was obtained through the courtesy of Dr. E. B. Carter, Abbott Laboratories, Inc., North Chicago, Illinois.

[3] Present address: Department of Animal Husbandry, A. & M. College of Texas, College Station, Texas.

[4] Present address: Department of Animal Industry, University of Florida, Gainesville, Florida.

age, 5 percent; and wheat, barley, cull peas, wheat bran and minerals. The average weight of the gilts at the beginning of the experiment was 299 pounds. The gilts were bred about 21 days before being placed on the purified ration, in an effort to insure conception prior to starting them upon the experimental rations. The animals were fed and handled in the same manner as described by Ensminger *et al.* (1947), with the same amounts of vitamins used. The gilts in both groups received a purified ration which consisted of casein, 26.1 percent; sucrose, 57.7 percent; lard, 11 percent; and a mineral mix, 5.2 percent.

The ration for the control gilts consisted of the purified ration supplemented with vitamins A, D, E, K, C, folic acid and the 6 B-complex vitamins, thiamine, riboflavin, pyridoxine, nicotinic acid, calcium pantothenate, and choline. Calcium pantothenate acid was omitted from the vitamin supplement fed the gilts in the pantothenic acid deficient lot. Otherwise the rations for the two lots were identical.

Observations and Discussion

The results reported herein are based upon observations with a limited number of animals on an obviously inadequate purified basal ration. Symptoms which developed in this trial were undoubtedly caused by complicated deficiencies.

The Control Gilts

Each of the three gilts fed the control basal ration farrowed normally. All pigs born, however, were either dead and in the process of resorption, or, if alive, were weak and died within 36 hours after birth. The average weight of the pigs farrowed, including dead animals, was 2.1 pounds. The animals in all the litters exhibited the same symptoms before death. These were characterized by a general nervous disorder and paralysis of the hind legs, making it impossible for the pigs to stand. When lying on their side, they kicked continually. The nervous symptom was characterized by a general, violent, trembling which was so intense that the pigs were unable to suckle unless held.

Autopsy of the pigs after death revealed excess clear fluid in the peritoneal cavity and pericardial sac. There were numerous petechiae on the kidneys. Lymph nodes were normal or appeared reddened and prominent. The brain appeared normal

Although the purified basal ration used for this trial contained adequate protein and all of the known required minerals and vitamins, it is evident that it was highly inadequate for satisfactory reproduction and lactation. This has been shown in previous work at this station by Ensminger *et al*

(1947) with swine, and Bowland *et al.* (1948) in work with rats. Likewise, Hogan and Anderson (1948) and Russell *et al.* (1948) has reported unsatisfactory results when using purified rations for reproduction in swine. Apparently other unknown dietary essentials are required for normal reproduction and lactation in swine. Biotin, inositol and paraaminobenzoic acid were not included in the vitamin supplement for this ration because they had been shown by Wintrobe (1939), McRoberts and Hogan (1944) to be of no additional benefit for the pig and did not appear to give any benefit with the purified ration. Although the gilts in this control lot were fed a ration similar to that used in the above-mentioned trials, the gilts in this year's trial failed even more completely in reproduction and lactation. This variation in results may have been partially caused by individual variations in the requirements of the animals and also to the fact that natural rations vary considerably in their composition from year to year. Since the gilts were maintained upon natural rations until the experiment was initiated, there may have been a difference in the amount of storage of the factor or factors. Cunha *et al.* (1944) and (1946a) have shown that sows have the ability to store these factors needed for reproduction and lactation for a considerable length of time.

TABLE 1. GESTATION RECORD

Item	Control group			Pantothenic Acid deficient group		
No. of gilts in trial		3			3	
Sow no.	146	160	152	69	105	75
Days on purified ration before farrowing	82	86	87	88	75	47
Initial weight per gilt (pounds)	291	304	260	315	340	286
Average daily gain until farrowing (pounds)	1.63	1.35	1.72	0.19	−0.66	0.00
No. of pigs farrowed per litter	10	10	8	11*	15*	9*
Average birth weight of pigs (pounds)	1.90	2.20	2.20	—	—	—
Per cent of pigs farrowed						
strong	0	0	0	—	—	—
medium	0	0	0	—	—	—
weak	80	90	87.50	—	—	—
Dead-macerating and partially resorbed	20	10	12.50	100	100	100

*Macerating and partially resorbed fetuses found in uterus on autopsy.

The Pantothenic Acid Deficient Gilts

The three gilts receiving the purified ration without pantothenic acid

developed a loss of appetite after 24 to 34 days on the ration. This was the first deficiency symptom observed, and was rather erratic in its appearance. After refusing all or part of their feed for a few days, animals often regained their appetites and consumed all of the feed allowed them for one or two weeks, after which they went off feed again. These intermittent periods of anorexia continued for about the first seven weeks of the experiment, after which the animals lost their appetites permanently. Inanition became progressively worse as the trial progressed, until all the gilts were losing weight rapidly when removed from the trials at the end of 47 to 88 days. It is interesting to note that as less feed was consumed, there was considerably less water consumed.

Characteristic goose-stepping with the hind legs was first observed after the gilts had been on the deficient ration for about two months, which increased in severity as the trial progressed. As this abnormality of gait increased, the animals became listless and greatly restricted in their activity. All animals exhibited a dark exudate of the skin which was especially prevalent about the eyes.

Two of the animals on trial developed a severe diarrhea accompanied by rectal hemorrhage in 34 and 44 days, respectively, after initiation of the trial. These conditions became so serious in the case of one gilt that she was removed from the experiment for autopsy at the end of 47 days. Examination revealed hemorrhagiconecrotic cecocolitis and a catarrhal gastro-enteritis. The uterine mucosa was pink in color and 9 dead fetuses were found in the uterine horns. The fetuses were in an advanced stage of resorption and maceration varying from 2.5 to 3.5 inches in length. They were brown in color.

The third gilt of the group developed a mild intermittent diarrhea, but the condition did not become severe and was not accompanied by hemorrhage.

The observed symptoms of inanition, diarrhea, listlessness and goose-stepping of the hind legs are similar to those which have been reported in younger pigs by Hughes (1939); Wintrobe *et al.* (1942), (1943); Follis and Wintrobe (1945); McMillen *et al.* (1948) and Colby *et al.* (1948).

The remaining two gilts, as they approached parturition dates, failed to exhibit any external signs of pregnancy, including a complete lack of mammary development. Shortly after the termination of their normal gestation period, when no signs of parturition had appeared, the gilts were sacrificed for autopsy. Upon examination, the digestive and reproductive tracts appeared normal except for the presence, respectively, of 11 and 15 dead and partially resorbed fetuses in the uterine horns of the two animals. The fetuses were identical in size and appearance with those found in the animal which had been previously examined. There was no evidence of enteritis or rectal

hemorrhage. Thus in all cases, even though the gilts which were deficient in pantothenic acid, conceived, they failed to show any external signs of pregnancy or mammary development. All the fetuses died during gestation and were in the process of resorption at the normal time for parturition.

Summary

The results of this trial indicate that, as in previous work, the purified control diet used was not adequate to support satisfactory reproduction and lactation in brood sows.

Gilts fed the purified ration supplemented with all known required vitamins did not reproduce satisfactorily although they were normal in appearance. They all farrowed within normal limits of the 114th-day gestation period and produced litters of normal numbers. Some of the pigs, however, were in the process of resorption at the time of birth. The remainder of the pigs were weak at birth and were affected with some type of nervous disorder. All died within 36 hours after birth.

The omission of pantothenic acid from the vitamin supplement produced a deficiency syndrome in the gilts which was characterized by loss of appetite, reduced water intake, goose-stepping with the hind legs and an exudate on the skin. Diarrhea and, in two instances, rectal hemorrhages were also observed in the animals fed this ration. Although all of these animals conceived, they did not farrow nor did they exhibit any external signs of pregnancy. Autopsy revealed partially resorbed, macerating fetuses in the uterine horns of these animals. A hemorrhagiconecrotic cecocolitis and catarrhal gastroenteritis was also found in all of the animals.

Literature Cited

Bowland, J. P., M. E. Ensminger and T. J. Cunha. 1948. Need for an Unidentified Factor or Factors for Growth, Reproduction and Lactation of Rats Fed Purified Rations. Arch. Biochem. 16: 257.

Colby, R. W., T. J. Cunha, C. E. Lindley, D. R. Cordy and M. E. Ensminger. 1948. Biotin-pantothenic Acid Interrelationship and Enteritis in the Pantothenic Acid Deficient Pig. J. Amer. Vet. Med. CX: 589.

Chick, H., T. F. Macrae, A. J. P. Martin and C. J. Martin. 1938. The Water Soluble B Vitamins Other Than Aneurin (vitamin B_1), Riboflavin and Nicotinic Acid Required by the Pig. Biochem. Jour. 32: 220.

Cunha, T. J., O. B. Ross, P. H. Phillips and G. Bohstedt. 1944. Wisconsin Agr. Exp. Sta. Unreported data.

Cunha, T. J., E. J. Warwick and M. E. Ensminger. 1946. Nutritional Adequacy of Cull Peas As a Protein Supplement for Growth, Reproduction and Lactation in Swine. JOURNAL OF ANIMAL SCIENCE 5: 419.

Ellis, N. R., L. L. Madsen and C. O. Miller. 1943. Pantothenic Acid and Pyridoxine as Factors in the Occurrence of Locomotor Incoordination in Swine. JOURNAL OF ANIMAL SCIENCE 2: 365.

Ensminger, M. E., J. P. Bowland and T. J. Cunha. 1947. Observations of the Thiamine,

Riboflavin and Choline Needs of Sows for Reproduction. JOURNAL OF ANIMAL SCIENCE 6: 409.

Follis, R. H. Jr., and M. M. Wintrobe. 1945. A Comparison of the Effect of Pyridoxine and Pantothenic Acid Deficiencies on the Nervous Tissues of Swine. Jour. Exp. Med. 81: 539.

Hogan, A. J. and G. C. Anderson. 1948. Vitamins Required by Swine for Growth, with Some Observations on Reproduction. Jour. Nutr. 36: 437.

Hughes, E. H., 1938. The Vitamin B-complex as Related to Growth and Metabolism in the Pig. Hilgardia 11: 595.

Hughes, E. H. 1939. The Role of Riboflavin and Other Factors of the Vitamin B-complex in the Nutrition of the Pig. Jour. Nutr. 17: 527.

Hughes, E. H. 1942. Pantothenic Acid in the Nutrition of the Pig. Jour. Agr. Research. 64: 185.

Hughes, E. H. and N. R. Ittner. 1942. The Minimum Requirement of Pantothenic Acid for the Growing Pig. JOURNAL OF ANIMAL SCIENCE 1: 116.

Krider, J. L., B. W. Fairbanks, R. F. Van Pouche, D. E. Becker, and W. E. Carroll. 1946. Sardine Condensed Fish Solubles and Rye Pasture for Sows During Gestation and Lactation. JOURNAL OF ANIMAL SCIENCE 5: 256.

McMillen, W. N., R. W. Luecke and F. Thorp, Jr. 1948. Pantothenic Acid Deficiency in Swine on Diets of Natural Feedstuffs. JOURNAL OF ANIMAL SCIENCE 7: 529.

McRoberts, V. F. and A. G. Hogan. 1944. Adequacy of Simplified Diets for the Pig. Jour. Nutr. 28: 165.

Russell, W. C., A. E. Teeri and D. Unna. 1948. Growth and Reproduction of Swine on a Purified Diet. Jour. Nutr. 35: 321.

Wintrobe, M. M. 1939. Nutritional Requirements of Young Pigs. Amer. Jour Physiol. 126: 375.

Wintrobe, M. M., M. H. Miller, R. H. Follis, Jr., H. J. Stein, C. Mushatt and S. Humphreys. 1942. Sensory Neuron Degeneration in Pigs IV. Protection Afforded by Calcium Pantothenate and Pyridoxine. Jour. Nutr. 24: 345.

Wintrobe, M. M., R. H. Follis, Jr., R. Alcayaga, M. Paulson and S. Humphreys. 1943 Pantothenic Acid Deficiency in Swine. Bull. of the Johns Hopkins Hospital. LXXIII: 313

COMPARISON OF HIGH AND LOW PROTEIN CORN FOR GROWING-FATTENING PIGS IN DRYLOT

F. A. Dobbins, J. L. Krider, T. S. Hamilton,
E. B. Earley[1] and S. W. Terrill[2]
University of Illinois[3]

SINCE there is an enormous production of corn in the United States, a complete knowledge of its nutritive value is of scientific interest and may be of great economic importance. Yellow dent corn is too low in protein and its protein is too deficient in essential amino acids, especially lysine and tryptophane, to be fed most efficiently to growing pigs in drylot without a good protein supplement. Today, certain hybrid strains of corn contain up to 20%, or even more, of crude protein because of genetic selection and adequate nitrogen fertilization. In the production of high protein corn, the varieties containing above approximately twelve percent protein apparently have somewhat lower yields.

Although whole corn protein is of low quality, the nutritional quality of corn germ protein is recognized as approximating that of animal proteins, both from feeding experiments and comparative amino acid analysis (Mitchell and Beadles, 1944) (Block and Bolling, 1944). Zein, the alcohol-soluble protein of corn, constitutes the major protein of the endosperm and is extremely low in both lysine and tryptophane. Osborne and Mendel (1914) demonstrated that zein was nutritionally incomplete since rats lost weight on a diet containing zein as the only source of protein. Normal growth was restored by the addition of lysine and tryptophane to the diet. Their findings were further substantiated in feeding experiments by Hogan (1916) and Marias and Smuts (1940), all of whom found that when zein or whole kernel corn was supplemented with lysine and tryptophane, normal growth occurred.

As the protein content of corn is increased the zein fraction increases more proportionally than the non-zein fractions. As zein contains little, if any, tryptophane, it might be expected that corn with higher zein content would contain less tryptophane than corn with lower zein content. Actually there is a positive correlation between the protein content and tryptophane content since the non-zein protein fraction (containing tryptophane) also increases as the zein increases.

[1] Department of Agronomy, Urbana, Illinois.

[2] Acknowledgment is made to Funk Bros. Seed Co., Bloomington, Illinois, for assistance in obtaining the samples of yellow corn.

[3] Animal Science Department, Urbana, Illinois.

In a comparison of waxy and non-waxy corn for pigs, Hanson (1946) found that 6.3 pounds less protein supplement per 100 pounds of gain was required with waxy corn containing 14% crude protein (dry basis) than with non-waxy corn containing 11% crude protein (dry basis).

McElroy and Draper (1949) conducted pig feeding trials using high, medium and low protein barley and oats. They state that when high protein barley and oats are used in the ration, good results can be obtained by adding substantially smaller quantities of protein supplement than are required when the grains used are of low protein content.

The three experiments reported herein were conducted to compare the protein quality of low and high protein corn and to provide a partial answer to the question of whether or not the higher protein corn can be fed with less protein supplement than is required when average or low protein corn is fed to growing-fattening pigs in drylot.

Experimental Procedure and Results

Experiment 1. Pilot Test with Rats (1949, spring)

The purpose of this pilot test was to compare yellow corns containing 8.6, 11.2, and 13.5 percent crude protein (fresh basis) when fed to young rats.

Twenty-four young, white, male rats weighing 56 grams initially were trio-fed (equal feed) for six weeks. Individual screen wire cages were provided each rat and automatic water bottles were attached to each cage.

Eight rats received the A diet (8.6 % protein corn), eight received the B diet (11.2% protein corn) and eight received the C diet (13.5% protein corn). The feed intake was controlled by the paired-feeding technique with the amount of feed given any one trio being determined by the smallest amount of feed consumed by any member of the trio. All animals were fed once daily and feed containers were left in the cages until the following day.

The crude protein content of all diets was 15%, and in each diet the amount of protein supplied by corn was the same. All three diets were equated for gross energy through the addition of corn starch and crude corn oil to the B and C diets. Wood flock was added to the B and C diets in order to equalize the fiber content of the three diets.

Rats were killed by etherization at the end of the test. Body length from tip of nose to base of tail was recorded for each rat. The carcasses were weighed after emptying the contents of the alimentary tract. They were then frozen and held in the frozen state until chemical analyses could be made.

The diets fed are given in table 1 and the results are briefly summarized

in table 2. The data in this test were analyzed statistically using the t-test for paired differences. The differences in average daily gains and body lengths were not statistically significant. These results indicate that the

TABLE 1. COMPOSITION OF DIETS FED TO RATS

Ingredients	Diet		
	A	B	C
Crude protein in corn[1]	8.6%	11.2%	13.5%
	lb.	lb.	lb.
Ground yellow corn	72.0	55.35	46.0
Supplement (38% C.P.)[2]	23.5	23.5	23.5
Corn starch (granular)	—	15.67	23.93
Crude corn oil	—	0.6	1.47
Wood flock	—	0.38	0.6
Vitaminized starch[3]	2.5	2.5	2.5
Complex mineral mixture	1.8	1.8	1.8
Vitamin A and D supplement[4]	0.2	0.2	0.2
Total	100.0	100.0	100.0
Protein content, by analysis	15.37	15.43	15.40
Energy in Cals. per gm.	3.94	4.03	3.97

[1] On a dry basis the corns contained 9.6%, 12.5% and 15.0% crude protein, respectively.
[2] Equal parts by weights of dehydrated alfalfa meal, solvent soybean meal and 50% meat and bone scraps.
[3] Containing all of the known water-soluble vitamins except biotin, folic acid and B_{12}.
[4] 5000 U.S.P. units Vitamin A per gm. and 1000 AOAC units Vitamin D per gm.

TABLE 2. SUMMARY OF RESULTS WITH RATS

(8 trios fed 42 days)

Items compared	Diets		
	A	B	C
Percent crude protein in corn	8.6	11.2	13.5
Av. initial weights, gm.	56	56	56
Av. final weights, gm.	210.7	208.0	209.5
Av. daily gain, gm.	3.68	3.62	3.66
Av. daily feed per rat, gm.	12.2	12.2	12.2
Av. feed per gm. gain, gm.	3.30	3.31	3.33
Milligrams N. per gm. gain	81.1	81.8	82.4
Av. body length, cm.	20.5	20.6	20.4

differences in protein quality of the three corns were so slight that they could not be detected by the feeding technique employed.

Carcass Analysis of Rats. Each frozen carcass was ground separately

through a common meat grinder and composite samples were taken for chemical analysis. The total nitrogen content of each carcass was determined by the Kjeldahl method and the gross energy determinations were made in a bomb calorimeter.

The results are given in table 3. A statistical analysis using the t-test for paired data showed no significant differences in the amount of gross energy per rat. Differences in grams of nitrogen per rat between diets A and C and between B and C were not significant, but differences between A and B were significant. This is difficult to explain since no significant difference was shown between A and C.

TABLE 3. SUMMARY OF RAT CARCASS ANALYSIS

Items compared	Diets		
	A	B	C
Number of rats	8	8	8
Av. frozen weight, gms.	208.1	206.1	206.8
Av. gross energy, Cal/gm	2.36	2.47	2.44
Av. percent total nitrogen	3.05	2.95	2.98
Av. nitrogen per rat, gms.	6.34*	6.08	6.17
Av. percent crude protein	19.04	18.46	18.63

* Significant over B ($P \leqq 0.02$).

Experiment 2. Paired-Feeding Test with Pigs (1949, summer).

The purpose of this experiment was to compare the supplemental value of corn protein from two varieties of yellow corn containing 8.2% and 11.7% crude protein (fresh basis) respectively, when fed to growing-fattening pigs in drylot.

Eighteen Chester White pigs weighing 56 pounds initially were pair fed (equal feed) for eight weeks. The members of each of seven pairs were of the same sex and from the same litter, while members of two pairs were of the same sex, but from different, though closely related litters. Young, lightweight pigs were used because the period of rapid growth offers a more critical test of protein because of the need for more and higher quality protein at this time.

All pigs were individually fed twice daily. They were placed in individual feeding crates (size 15″×32″×4′) at feeding time only. At other times the pigs were confined on concrete floors as two groups of nine pigs each, in a pen measuring 27′×16′. Water was available at an automatic waterer in each pen.

All pigs were individually weighed at weekly intervals.

The pigs received a 15% crude protein ration until they reached 100 pounds and 12% thereafter. Although these levels of crude protein are suboptimum for pigs of these weights, they were used to give a more critical test of the value of the protein in the rations. The two rations were equated for gross energy and crude fiber by adding corn starch, crude corn oil and wood flock to the B rations.

Table 4 shows the composition of the rations fed and the crude protein (N × 6.25) and gross energy content of all rations as determined by chemical analysis. In each ration the amount of protein furnished by corn was the same and therefore less of the higher protein corn was required in each case.

TABLE 4. COMPOSITION OF RATIONS FED TO PIGS IN EXPERIMENT 2

Items compared	Up to 100 lb.		Over 100 lb.	
	A	B	A	B
Crude protein in corn[1]	8.2%	11.7%	8.2%	11.7%
Ground yellow corn	75.0	53.5	85.0	59.5
Supplement (38% C.P.)[2]	23.0	23.0	13.0	13.0
Corn starch, granular	—	20.0	—	23.74
Crude corn oil	—	1.0	—	1.20
Wood flock	—	0.5	—	0.56
Complex mineral mixture	1.8	1.8	1.8	1.8
Vitamin A and D supplement[3]	0.2	0.2	0.2	0.2
Total	100.0	100.0	100.0	100.0
Crude protein content, by analysis, %	15.2	15.6	11.3	11.6
Energy in Cals. per gm.	3.78	3.81	3.79	3.80

[1] Corns contained 9.6% and 13.8% crude protein on dry basis, respectively.

[2] Equal parts by weight of dehydrated alfalfa meal, solvent soyben meal and 50% meat and bone scraps.

[3] 5000 U.S.P. units Vitamin A/gm. and 1000 AOAC units Vitamin D/gm.

Note: Pantothenic acid, riboflavin and choline were added in crystalline form to all rations to furnish the recommended levels of each.

A summary of results is shown in table 5. The pigs gained at the same rate (1.34 lbs. daily) and an analysis using the t-test for paired data showed no significance. All pigs performed satisfactorily and at the conclusion of the test the greatest weight difference between the members of a pair was four pounds. The pigs were not slaughtered for carcass studies but observations made of the live pigs indicated no marked differences in the degree of finish or growth. It is concluded that yellow corn containing 11.7% crude protein (fresh basis) is no better for young growing pigs than yellow corn containing 8.2% crude protein (fresh basis) when each supplies the same amount of protein in the ration.

TABLE 5. RESULTS OF FEEDING 8.2% AND 11.7% PROTEIN CORN TO PIGS PAIR-FED IN DRYLOT

Items compared	A	B
Crude protein in corn	8.2%	11.6%
Av. initial weight, lb.	56	56
Av. final weight, lb.	132	132
Av. daily gain, lb.	1.34	1.34
Av. daily feed per pig, lb.	4.04	4.04
Av. feed per 100 lb. gain, lb.	300	300

Experiment 3. Trio-Feeding Test with Pigs (1949–50 winter).

The purpose of this experiment was to compare the feeding value of yellow corns containing 7.7%, 9.1%, and 12.8% crude protein (fresh basis) for growing-fattening pigs in drylot.

Ten trios of 58 pound pigs were trio-fed (equal feed) for five weeks and five of the trios were continued on test for 10 weeks and were given the same accommodations as those used in experiment 2. Durocs, Chester Whites, and Poland Chinas were used. A trio consisted of three pigs of the same sex, from the same litter, and of approximately the same initial weight. Each trio was treated as a separate unit; one member received ration A, the second member received ration B, and the third member received ration C. All pigs were hand-fed individually twice daily.

All pigs were fed a ration containing 15% crude protein until they weighed 100 pounds and thereafter were fed a ration containing 12% crude protein. Although these levels of crude protein are suboptimum for pigs of these weights, they were used to give a more critical test of the value of the protein in the rations. The three diets contained the same amount of corn and enough supplement was added to balance the rations at 15% and 12% crude protein, respectively. Smaller amounts of supplement were required with the higher protein corn in the B and C rations. Corn starch and crude corn oil were added to the B and C diets to equate the gross energy content of the three rations and wood flock was added to equalize the fiber content of all rations. The dehydrated alfalfa meal was included at the same level in all rations as a vitamin supplement. The rations are given in table 6.

A summary of the results is presented in table 7. The average daily gains did not differ significantly between lots of pigs fed either the 7.7% or the 9.1% protein corn for the five-week or the ten-week period. However the the average daily gains made by pigs fed the 12.8% protein corn (ration C) were significantly less than the average daily gains of pigs fed either the 7.7% or 9.1% protein corn. Under the conditions of this experiment, the 12.8%

TABLE 6. COMPOSITION OF RATIONS FED TO PIGS IN EXPERIMENT 3

Ingredients	Up to 100 lb.			Over 100 lb.		
	A	B	C	A	B	C
Crude protein in corn[1]	7.7%	9.1%	12.8%	7.7%	9.1%	12.8%
Ground yellow corn	74.5	74.5	74.5	84.0	84.0	84.0
Dehydrated alfalfa meal (20% crude protein)	7.0	7.0	7.0	5.0	5.0	5.0
Supplement (47% crude protein)[2]	16.5	14.5	8.58	9.0	6.5	—
Corn starch	—	1.79	7.11	—	2.24	8.07
Crude corn oil	—	0.13	0.50	—	0.16	0.57
Wood flock	—	0.08	0.31	—	0.1	0.36
Mineral mixture	1.8	1.8	1.8	1.8	1.8	1.8
Vitamin A & D supplement[3]	0.2	0.2	0.2	0.2	0.2	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0
Crude protein content (by analysis)	14.9%	15.0%	15.0%	11.5%	11.7%	11.8%

[1] Corns contained 9.1%, 10.9% and 15.4% crude protein on dry basis, respectively.

[2] Equal parts by weight of solvent soybean oil meal (44% crude protein) and meat and bone scraps (50% crude protein).

[3] 5000 U.S.P. units Vitamin A and 1000 AOAC units Vitamin D per gram.

Note: Pantothenic acid, riboflavin and choline chloride were added in crystalline form to all rations to furnish the recommended levels of each. At the end of five weeks 1.5% of Lederle's APF supplement was added to each of the rations.

TABLE 7. RESULTS OF FEEDING 7.7%, 9.1% AND 12.8% PROTEIN CORN TO PIGS TRIO-FED IN DRYLOT

Items compared	Ten trios fed for 5 weeks			Five trios fed for 10 weeks		
	Rations			Rations		
	A	B	C	A	B	C
Number of pigs	10	10	10	5	5	5
Number days on test	35	35	35	70	70	70
Av. initial weight, lb.	58.1	58.0	58.0	60.2	59.6	60.2
Av. final weight, lb.	94.6	94.7	91.6	156.0	152.8	145.8
Av. daily gain, lb.	1.04**	1.05*	.96	1.37*	1.33**	1.22
Av. daily feed per pig, lb.	2.94	2.94	2.94	3.98	3.98	3.98
Feed eaten per 100 lb. gain, lb.	282.2**	280.7*	306.6	291.1*	299.2**	325.8

* Significant over C ($P \leq 0.05$).

** Highly significant over C ($P \leq 0.01$).

protein corn did not satisfactorily replace half of the supplement in het rations fed to 100 pounds live weight or all of the supplement in the rations fed thereafter for growth of young pigs. The feed required per 100

pounds of gain made by pigs fed the 12.8% protein corn was significantly greater than the feed required by pigs fed either the 7.7% protein corn or the 9.1% protein corn in rations equated for crude protein. The 9.1% protein corn satisfactorily replaced 2 pounds or 12.1% of the protein supplement in the rations fed up to 100 pounds live weight and 2.5 pounds or 27.8% of the protein supplement for over 100 pounds live weight.

Discussion

As the percentage of total protein of corn increases, an increasing proportion of such protein is made up of zein, which is extremely low, if not completely devoid of lysine and tryptophane. Therefore, one would assume that the quality of the protein in high protein corn is inferior to that in low protein corn. However, the rat experiment and first pig experiment in which high protein and low protein corn furnished the same amount of protein in the rations, clearly show that the difference in protein quality in the corns used is so slight that it cannot be demonstrated by the feeding techniques employed.

All experimental evidence to date indicates that corn, regardless of its protein content, will not satisfy the amino acid requirements of growing swine. Therefore, an efficient protein supplement should be fed with high protein corn as well as with low protein corn for growing-fattening pigs.

Twelve percent less protein supplement (equal parts of solvent soybean oil meal and meat and bone scraps) was needed to produce a 15% protein ration and 27.7% less protein supplement was needed to produce a 12% protein ration when the 9.1% protein corn was used than when the 7.7% protein corn was used. Since the rations contained suboptimum levels of protein for young growing pigs it seems logical to assume that in rations formulated to contain the recommended protein levels, the high protein corn will replace a higher percentage of the protein supplement than the above figures indicate.

Since ground mixed rations were fed in the experiments reported herein, there was no attempt to determine differences in the palatability of the various corns. All rations were readily consumed and were equally palatable to the pigs. However, palatability of certain varieties of high protein corn may become a limiting factor when the shelled corn is self-fed free-choice. Some preliminary work at the Illinois Station indicates that palatability is not an important factor, but further work is planned to determine the importance of palatability when high protein corn is self-fed free-choice with protein supplement.

The reduction in the amount of protein supplement needed to balance the protein content of the ration when high protein corn is fed will depend

on such factors as (1) the protein content of the corn, (2) the proportion of the protein in the germ and the proportion in the horny endosperm and (3) the type of supplement used. A supplement high in both lysine and tryptophane will supplement more efficiently the protein in high protein corn.

Summary

Young male rats were trio-fed (equal feed) for six weeks on diets equated for crude protein (15%) and energy to compare yellow corns containing 8.6%, 11.2% and 13.5% crude protein (fresh basis). In each diet the amount of protein supplied by corn was the same. No significant differences occurred in growth rates or in gross energy content of the carcasses.

In a similar test with nine pairs of pigs pair-fed (equal feed), yellow corn containing 11.7% protein was no better than yellow corn containing 8.2% protein when each furnished the same amount of protein in the ration.

In another experiment with pigs (trio-fed, equal feed) fed equal amounts of corn containing 7.7%, 9.1% and 12.8% crude protein, with enough protein supplement to raise all rations to a 15% protein level (12% after the pigs reached 100 pound weight), average daily gains made by pigs fed the 12.8% protein corn were significantly less than those made by pigs fed the corn of lower protein content. Average daily gains did not differ significantly between pigs fed either 7.7% or 9.1% protein corn. Twelve percent less protein supplement was needed to produce a 15% protein ration and 27.7% less supplement was needed to produce a 12% protein ration when the 9.1% protein corn was used than when the 7.7% protein corn was used.

Literature Cited

Block, R. J. and Diana Bolling. 1944. Nutritional Opportunities with Amino Acids. Jour. Amer. Diet Assoc. 20: 69.

Frey, K. J., B. Brimhall and G. F. Spraque. 1949. The Effects of Selection Upon Protein Quality in the Corn Kernel. Jour. Agron. 41: 399.

Hanson, L. E. 1946. Waxy versus Non-Waxy Corn for Swine. JOURNAL OF ANIMAL SCIENCE 5: 36.

Hogan, A. G. 1917. Corn as a Source of Protein and Ash for Growing Animals. Jour. Biol. Chem. 29: 485.

Marias, J. S. C. and D. B. Smuts. 1940. The Biological Value of the Proteins of Maize and Maize Supplemented with Lysine and Tryptophane. Onderstepoort Jour. Vet. Med. 15: 197.

McElroy, L. W. and Draper, H. H. 1949. Feeding Grains of Different Protein Content to Growing Pigs. Sci. Agric. 29: 579.

Mitchell, H. H. and Jessie R. Beadles. 1944. Corn Germ: A Valuable Protein Food. Science 99: 129.

Osborne, T. B. and L. B. Mendel. 1914. Amino Acids in Nutrition and Growth. Jour. Biol. Chem. 17: 325.

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE FORTY-SECOND ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Hotel Sherman in Chicago on November 24 and 25, 1950 with a dinner for the honor guest on November 26. Abstracts have been submitted for the following papers.

Breeding and Genetics Section

H. H. Stonaker, *Chairman*

EVALUATING THE INHERITANCE OF BUTTERFAT PRODUCTION OF YOUNG DAIRY SIRES FROM THEIR PEDIGREES. Robert H. Benson and W. J. Tyler, *West Virginia University.*

Two-generation pedigrees of 348 proven Ayrshire bulls born after January 1, 1942, were studied to determine the reliability of using pedigree information to predict the production of a bull's daughters. Since most bulls are selected as calves, only data that were available on the ancestors and other close relatives before each bull was 8 months old were used. All records were adjusted to an M. E. 2 × 305 day basis and were furnished by the Ayrshire Breeders' Association. Correlation and regression coefficients were computed between the butterfat production of different relatives in the pedigree and the average production of each bull's daughters. The correlation coefficient between sire's daughters and bull's daughters was 0.12; between paternal grandsire's daughters and bull's daughters −0.07; between paternal granddam's first 3 records and bull's daughters −0.03; between dam's first 3 records and bull's daughters 0.20; between maternal grandsire's daughters and bull's daughters −0.07; between maternal granddam's first 3 records and bull's daughters 0.04; and between bull's mates and bull's daughters 0.41. The corresponding regression coefficients are 0.18, −0.15, −0.03, 0.18, −0.11, 0.03 and 0.48. The coefficients between bull's daughters and dam's performance and between bull's daughters and their dams (bull's mates) were highly significant. None of the other coefficients were significant. There were 118 bulls that were by proven sires and also out of tested dams. The correlation and regression coefficients computed on these 118 pedigrees indicated that dam's performance was equal to records on paternal half sisters in predicting the production of a bull's daughters.

STUDY OF THE USE AND EFFECTIVENESS OF A SWINE SELECTION INDEX ON WISCONSIN FARMS. C. S. Bernard, K. T. Trimble, A. B. Chapman and D. H. Williams, *University of Wisconsin.*

An estimate is made of the extent to which a selection index recommended to farmers in the Wisconsin Swine Selection Cooperative was actually differentiating animals within herds on the basis of weight for age and the productivity of their dams. Selection intensities and differentials and probable effectiveness of selection were also calculated .The factors considered were: number farrowed (NF), number weaned (NW), number at 154 days (N_{154}), weight of the individual at 154 days (WI_{154}), the weight of the litter weaned (WLW), and at 154 days (WL_{154}). A significant difference existed between high-, medium-, and low-index thirds for each of the characters considered. The selection intensities for gilts were calculated on 48 herds over a two year period and found to be 45.3% and 32.9% respectively. The net selection differentials in terms of standard deviations for each of the years were: NF = .22 & .58; NW = .30 & .20; N_{154} = .32 & .62; WI_{154} = .52 & .59; WLW = .30 & .36; WL_{154} = .42 & .67. The comparable conscious selection differentials for the two years

were: NF = −.03 & .28; NW = −.04 & .12; N154 = .16 & .34; WI154 = .52 & .59; WLW WLW = .11 & .01; WL154 = −.21 & .41. The means for each of the above characters for those gilts recommended on the basis of index but not selected as replacements were significantly higher than the means for each one of the same characters for those selected but not recommended. The recommended and selected gilts differed significantly from those not recommended and selected within the same herds for all of the characters included in the gilts' own selection index. The averages for NF, N154, WI154, in the next generation of these two groups did not differ significantly but the means were higher in the "recommended" group in each of the herds studied.

SOME FACTORS AFFECTING BIRTH WEIGHTS OF BEEF CALVES. M. J. Burris C. T. Blunn, and M. L. Baker, *University of Nebraska.*

Data from birth records of calves collected at the University of Nebraska from the purebred Angus, Shorthorn and Hereford herds were analyzed as to variance and covariance. The regression of birth weight on gestation and the regression of birth weight on age of dam were found to be highly significant. Highly significant differences were noted between the three breeds and between the two sexes. Variance due to years, sires, interaction of years and breed, interaction of sex and sire, and interaction of sex and breeds were not significant at the 5 percent level. An analysis of variance of the gestation lengths showed a highly significant difference in the gestation periods for the two sexes and for the three breeds. In an attempt to measure the repeatability of calf weights it was noted that weights of calves from the same dam tend to be correlated. Correlation between the age of dam and length of gestation was not significant at the 5 percent level.

ADDITIONAL INFORMATION ON THE INHERITANCE OF HORNS IN SHEEP. H. W. Carter and W. L. Henning, *The Pennsylvania Agricultural Experiment Station.*

A study of the inheritance of horns in sheep was made on 630 cross-bred lambs. These crosses involved Dorset Horn (both sexes horned), Merino (horned males; hornless females), and hornless breeds (both sexes hornless). The following observations were made: (1) that the horns of the Dorset and those of the Merino are due either to different genes or an inhibiting factor is involved in the Merino; (2) that the factors causing the polled character in the female of the Hampshire and the other hornless breeds and hornless females in the Merino breed are different as shown by breeding the two types to the Dorset Horn. When Dorset $\times$ Merino F_1 females were bred to Hampshire rams the following horn condition was obtained: in the males, 4 large horn, 5 small horn, 15 normal scurs, 12 slight scurs, 6 polled; in the females 50 polled, 1 slight scur. The results of this three-breed cross would indicate that in the male: (a) a horn modifying gene is carried either in the $D \times M_{F1}$ ewes or the Hampshire rams in a heterozygous condition; (b) that scurs are due either to a further modifying gene of the horn to a character for scurs which is incompletely dominant or is affected by a modifying factor; (c) that the factor causing the polled condition in the Hampshire must be dominant in the female, and that this dominant polled character also inhibits the growth of scurs in the female.

HETEROSIS IN CROSSES OF INBRED LINES OF DUROC SWINE. Doyle Chambers and J. A. Whatley, Jr., *Oklahoma A. and M. College.*

Litter weights and number of live pigs per litter at birth, 21, 56, and 180 days were the items studied on 444 litters of Duroc swine at the Oklahoma Station. These litters included inbred litters from seven different unrelated lines, single cross litters among these lines, three-line cross litters, and outbred Duroc litters. All litters were either from gilts or were corrected to a gilt equivalent age using correction factors computed from the data. Intraseason weighted mean differences were obtained for the different comparisons on each of the items studied. Single cross litters were superior to inbred litters with the same line of dam at birth, 21, 56, and 180 days by .43, .76*, .85*, and 1.08** pigs per litter and by 1 2, 7 4, 23.5*. and

* $P < .05$ ** $P < .01$

181** pounds per litter. From weaning to 225 pounds, single cross pigs fed in dry lot gained .03 of a pound more per day and required six pounds less feed per 100 pounds of gain than did the inbreds. Three-line cross litters contained 1.36*, 1.15*, 1.20*, and 1.66 more pigs than did single cross litters at the four ages and were 2.9*, 9.6*, 29.7*, and 298* pounds heavier at the same time. The three-line cross litters exceed outbred Durocs by approximately the same amount. There was no significant difference in the performance of single cross and outbred litters. Heterosis was expressed to a greater extent in the increased viability of the pig and productivity of the line cross gilts than in the increased growth rate of the pig or its efficiency of gain.

WHAT BECOMES OF ANIMALS BORN IN A DAIRY HERD DURING FORTY-FOUR YEARS. H. P. Davis, *University of Nebraska.*

At the University of Nebraska the dairy herd, consisting of pure bred animals of the Holstein, Jersey, Guernsey, and Ayrshire breeds, has been in charge of three departmental chairmen during the period and has had a continuity of operation not often experienced. During that time there were 2362 calvings which resulted in the birth of 1250 males and 1178 females a sex ratio of 51.48 percent males and 48.52 per cent females or 106.1 males to 100 females. There was a slight difference between the breeds in this respect both the Ayrshires and Guernseys having slightly more females than males. There were 149 abortions or 6.35 percent of the total calvings. but after the elimination of Brucellosis, this percentage dropped during the last 14 years to a figure slightly over three percent. There were 66 sets of twins, 0.85 percent males, 1.19 percent males and females, and 0.76 percent females, a total which represented 2.79 percent of all calvings. Calves born alive were 87.76 percent for males and 90.75 percent for females, or an average of 89.21 percent. The breeds showed a slight difference in this respect as follows: Guernseys having 88.24; Jersey 89.14; Ayrshires 91.23; and Holsteins 91.53 percent born alive. For males 5.56 percent entered the herd, the remainder were disposed of as follows: sold for breeding 50.68 at an average price of $126.26; sold for beef 18.05 percent at an average price of $17.11; used for experiments 9.85 percent; and died from all causes 15.86 percent. For the females, 74.84 percent entered the herd; 7.02 percent were sold for breeding at an average price of $90.20; 3.84 per cent were sold for beef at an average of $39.17; 0.65 percent were used for experiments, and 13.66 percent died from all causes. The death losses for all calves were 12.14 percent for the first three months, 1.71 precent for the second six months, and 0.92 percent for the remaining eighteen months. As between the breeds the losses from disease in percentage were: Holsteins 12.39; Aryshires 13.33; Jerseys 16.21; and Guernseys 20.06. For both sexes and all breeds, the disposals were as follows in percentage: sold for breeding 29.13; sold for beef 11.03; experimental 5.31; losses from disease 14.77; and entered the herd at two years 39.75.

GENERAL AND SPECIFIC COMBINING ABILITIES IN MOUSE CROSSES. O. N. Eaton, W. E. Neville and G. E. Dickerson, *U.S.D.A. and University of Missouri.*

All 72 crosses among 9 highly inbred strains were made in 549 litters at Beltsville during five years. Variability among unweighted means of the crosses was analyzed into portions due to line differences in average transmitted and in direct maternal influences, to deviations of individual crosses from average expectation and to experimental error. Percentages of total variance ascribed to the first three of these sources were, respectively, 7.5, 25.6* and 18.8 for litter size born; 4.1, 16.5 and 16.5 for litter size 15 days; 0, 12 and 12 for litter size 45 days; 21.7*, 43.5* and 0 for mouse weight 15 days; 44.8*, 35.7* and 1.9 for mouse weight at 45 days; 16.1, 0 and 16.8 for litter weight at 45 days. Line differences in transmitted influence were important only for mouse weight. Those in maternal influence were important for both litter size and mouse weight, but, because of $-.85$ correlation between these components, were non-existent for total litter weight at 45 days.

Specific linecross combination effects were important though not significant for viability

* Signifies $P < .01$.

and total litter weight, but not for mouse weights. Transmitted and environmental influences on viability were positively correlated with corresponding influences on mouse weight. Ratios of variances from specific and general cross performance, assuming epistasis negligible, suggest heterozygote superiority for viability ($k = 2$ to 3) and total litter weight ($k = 1.4$), but little dominance for genes influencing mouse weights. However, regressions of F_1 on inbred parent, within common parent lines, indicate much dominance for 45 day weight.

FEED LOT PERFORMANCE OF STEERS PRODUCED BY SCIENTIFIC BREEDING PROCEDURES COMPARED WITH STEERS FROM RECOGNIZED COMMERCIAL SOURCES. Paul Gerlaugh and L. E. Kunkle, *Ohio Agricultural Experiment Station.*

Three lots of yearling steers produced by scientific breeding procedures at the United States Range Livestock Experiment Station were compared with check lots of commercial feeder steers obtained at the Kansas City and St. Paul markets for rate and efficiency of gain in the feed lot, 196 days, and for dressing percentage and grade of carcass. All three lots of steers from the U. S. Range Experiment Station were sired by inbred bulls that had made a good showing in a record of performance feeding test. Two of the lots were from closed herds; the third group was from dams unrelated to the sires. No sorting for quality was done in these three lots. The steers from the markets were sorted. All lots were similarly fed. All three lots of steers from the U.S.D.A. Station outgained the check lots by about 9 percent and were about 8.5 percent more efficient. The check lots outdressed by 1.5 percent, but did not yield carcasses that graded as high as the steers from the Range Experiment Station.

INFLUENCE OF INBREEDING AND PLANE OF NUTRITION ON RATE AND ECONOMY OF GAINS, DIGESTION AND CARCASS COMPOSITION OF PIGS. K. E. Gregory and G. E. Dickerson, *University of Missouri.*

Sixteen representative pigs were selected at weaning from each of eleven breeding groups. The groups were two inbred lines of Polands and one of Hampshires, non-inbred Durocs, their six crosses and Poland linecross gilts mated to Duroc boars. Each group was divided into two lots of eight pigs, equalizing sex, litter and initial weight as well as possible. One lot was full-fed, the other limited. When crossline pigs were limited to the same level of intake as the parental inbred pigs, they showed a marked superiority in rate and economy of gain. The advantage of full-fed crosses was even greater in rate of gain but less in economy. The top cross pigs did not show any marked advantage over the outbred Durocs in rate and economy of gain. Digestion trials, using the "chromium oxide ratio technique," indicated no differences between breeding groups or feedling levels in ability to digest the ration. Limited-fed pigs gained .1 to .2 pound less per day than the full-fed pigs in the same cross, but, with the exception of one cross, the limited-fed pigs required less feed per unit of gain. In carcass desirability at 205 pounds live weight, crossline pigs were intermediate to inbreds of the parental lines. Outbred Durocs were poorest, but the top crosses were near the inbred lines in carcass desirability. The limited-fed pigs dressed from 1% to 2% less, produced less fat, had greater muscular development, and yielded primal cuts of higher quality than did the full-fed pigs. However, there were no consistent differences in yield of loin equivalent, adjusted for quality, between feeding levels.

A STUDY OF MEAT CHARACTERISTICS OF KARAKUL SHEEP. O. G. Hankins, R. L. Hiner and V. L. Simmons, *U. S. Department of Agriculture.*

The principal objective was to obtain an evaluation of the mutton qualities of Karakul sheep. Of the 57 ewes studied, 12 were purebred Karakul and the remainder were grades (75.0 to 99.80 percent Karakul) consisting of 22 Karakul × Blackfaced Highland, 15 Karakul × Corriedale, and 8 Karakul × Navajo. They ranged from 10 months to 10 years, 11 months in age, averaging 4.8 years. The variation in liveweight (unshorn) was from 66 to 163 pounds, the mean being 101.5 pounds. With respect to carcass and meat characteristics *per se*, dressing percentage, for example, ranged from 30.6 to 55.4 and the mean value was 44.8. Other examples of important characteristics were carcass grade with a low of "low Cull," and a high

of "high Good"; yield of rib cut, 5.00 and 10.60 percent; fatness (rib cut sample) 2.05 and 44.26 percent; and tenderness, "very tough" and "tender." Corresponding mean values for carcass grade, yield of rib cut, fatness (rib cut), and tenderness were "Medium," 7.59 percent, 25.52 percent and "slightly tough," respectively. Classified data indicated that important meat characteristics were not closely related to age of animals. Fatness was a more significant controlling factor as shown by increases from 30.6 to 51.1 in dressing percentage and from "low Cull" to "high Good" in carcass grade which accompanied an increase in fat content from 2.05 to 42.24 percent. Moreover, tenderness increased considerably with an increase from 19.67 to 42.24 percent in rib fatness. Both flavor of fat and flavor of lean were in general moderately high with respect to desirability.

GENETIC CORRELATION BETWEEN TYPE AND PRODUCTION IN JERSEYS. Walter R. Harvey and Jay L. Lush, *Iowa State College.*

The official type ratings and fat production records on 8,464 Jersey cows from 245 HIR herds which were tested at least 4 of the 5 years, 1943 to 1947 inclusive, were used in this study. All records of production were converted to a 2 × 305 day mature equivalent basis. Estimates of the genetic correlation were .18 from 2,786 daughter-dam pairs, .12 from the paternal sister analysis, .21 from the maternal sister analysis, and −.26 from 519 sets of full sisters. The paternal and maternal sister analyses contained all 8,464 cows which were sired by 2,605 sires and out of 6,912 dams. Twice the intra-herd regression of daughter on dam gave heritability estimates of .14±.04 for official type ratings and .18±.03 for single records of fat production adjusted for yearly differences. The intra-herd phenotypic correlation between an official type rating and a single record of fat production on the same cow was .12. The intra-herd phenotypic correlations among paternal, maternal, and full sisters adjusted for yearly differences, were, .14, .12, and .16 respectively for type and .12, .08, and .09 respectively for single records of fat production. Selection indexes were developed and will be presented in which some frequently met combinations of information about the phenotypes of the cow and her dam were included.

PERFORMANCE OF CROSSES BETWEEN SIX INBRED LINES OF SWINE. H. O. Hetzer, O. G. Hankins and J. H. Zeller, *U. S. Department of Agriculture.*

Single crosses between six inbred lines of swine developed at Beltsville, Md. were compared with inbreds in two seasons. The data included 35 inbred litters and 184 single-cross litters, representing all 30 possible reciprocal crosses. Intra-year differences between pairs of inbreds and their corresponding reciprocal crosses were used as the primary observations in analyzing the data. Inbreeding of litters averaged 28 percent for inbreds and 4 percent for single crosses. For each 10 percent increase in inbreeding, with age and inbreeding of dam constant, litter size at birth, 21 and 56 days declined by 0.51, 0.70 and 0.71 pigs, and litter weight by 1.0, 7.4 and 26.5 pounds. Pig weight at the same ages, after adjustment for both age and inbreeding of dam and litter size, declined by 0.01, 0.3 and 1.4 pounds and by 1.7 and 2.8 pounds at 98 and 140 days, respectively. Mortality was lower among crosses than among inbreds, by 1.2 pigs per litter or 14 percent at birth, by 1.7 pigs or 27 percent at 21 days and by 1.7 pigs or 29 percent at 56 days. In litter weight, crosses exceeded inbreds by 2.4 pounds or 10 percent at birth and by 64 pounds or 40 percent at weaning. In individual pig weight, differences in favor of crosses were 0.7 pound or 7 percent at 21 days, 3.5 pounds or 13 percent at 56 days, 4.6 pounds or 6 percent at 98 days and 7.3 pounds or 5 percent at 140 days. Slaughter data showed no significant differences between crosses and inbreds, except in thickness of back fat, crosses exceeding inbreds by 1.5 mm.

A GENETIC INVESTIGATION OF CERTAIN ALLOMETRIC GROWTH CONSTANTS IN HEREFORD CATTLE. James F. Kidwell, P. W. Gregory and H. R. Guilbert, *University of California.*

An investigation was made to determine whether the allometric equation, $\text{Log } y = K + a \text{ Log } x$, where $K = \text{Log } b$, would provide a quantitative measure of conformation and if the

constants of the equation could be used as selection criteria for altering conformation genetically. The data consist of measurements of weight, height at withers, height at hooks, heart girth, round, body length, head length, head width and width of hooks taken at birth, 4, 8, 12 and 16 months of age on 55 male and 52 female progeny of ten sires. Heart girth was selected as a standard of body size and each of the remaining dimensions compared with it in a series of Type E allometric equations. For all such comparisons the value of "a" changes markedly between birth and one month of age, but remains nearly constant thereafter. The allometric equation was found to provide a satisfactory quantitative description of conformation. Heritability of "a" and K was estimated by the half sib correlation method. In general, the parameters of equations relating linear skeletal dimensions are heritable, while those involving muscular or fatty tissues are not highly heritable. Large negative phenotypic, genetic and environmental correlations between "a" and K were observed in each instance. The consequences of these correlations are: (1) The relationship between "a" and K cannot be changed by selection. (2) The "a"-K complex can be modified by selection. (3) At least two points are required to define a unique genotype for the "a"-K complex. It may be concluded that the allometric equation provides a quantitative description of beef cattle conformation and that conformation might be changed in a specific manner by selection for desired values of the parameters.

FEEDLOT AND CARCASS CHARACTERISTICS OF HEREFORD STEERS OF SMALL AND CONVENTIONAL TYPES. H. H. Stonaker, M. H. Hazaleus, and S. S. Wheeler, *Colorado Agricultral Experiment Station.*

Twelve Hereford bulls of small and conventional types were bred to 205 purebred Hereford cows of small and conventional types over a three year period. Type classifications were made visually. From these matings all male calves were castrated and placed on individual feeding at weaning time. They were fed to a constant finish grade of low choice. Weaning weights, feeder grades, body measurements, individual feed consumption per pound gain, rate of gain, and carcass characteristics were recorded. The 24 small type steers produced during this period have been compared with 65 conventional type steers. Small type steers have had significantly smaller rates of gain, slaughter weights, carcass weights and weights of carcass cuts. For most of these characteristics the weights have been approximately 20 percent less than those of conventional types. Significant differences have not been found in days on feed, digestible nutrients per pound of gain, percent of carcass in the different wholesale cuts, or percent of separable fat, lean, and bone in the 9-10-11 rib cut.

THE ACCURACY AND REPEATABILITY OF LIVE-ANIMAL AND PHOTOGRAPHIC MEASUREMENTS OF BEEF CATTLE. H. G. Smith, C. S. Hobbs, E. J Warwick and W. M. Whitaker, *Tennessee Agricultural Experiment Station.*

Data from 43 animals including 10 cows, 23 yearlings and 10 calves were analyzed to determine the relative accuracy and repeatability of live-animal and photographic measurements of beef cattle. Generally high estimates of repeatability were obtained for the body measurements studied; namely (1) length of body, (2) height at withers, (3) depth of chest, and (4) patella to patella (live-animal measurements). Estimates of repeatability for body length for the three age groups varied from .546 to .898 for live-animal measurements and .726 to .844 for photographic measurements. Repeatability for height at the withers ranged from .888 to .906 for live-animal measurements and .908 to .927 for photographic measurements. For depth of chest, estimates of repeatability varied from .784 to .914 for live-animal measurements and .807 to .908 for photographic measurements. Repeatability for the round measurement (patella to patella) was lower than those for the other items studied with a range of .463 for the cows to .769 for the yearlings. Size did not appear to have any appreciable influence upon the errors of measurement although they were slightly greater for the larger animals. Estimates of repeatability, including both live-animal and photographic measurements, varied from .546 to .918 for the cows, .762 to .914 for the yearlings, and .807 to .927 for the calves. Photographic measurements gave slightly higher estimates of repeatability in a majority of cases with

differences of greatest magnitude occurring in body length of cows and yearlings. Differences between measurements of the two men and between measurements taken at different times of day were too small in almost every case to be significant.

CORRELATIONS BETWEEN TRAITS OF RANGE RAMBOUILLET RAMS. Clair E. Terrill, W. H. Kyle and L. N. Hazel, *U.S.D.A.*

The rams used were born from 1938 through 1942, the number gradually decreasing from 502 yearlings to 31 five-year olds. Repeatability of weanling traits at yearling age was 0.76 for weaning weight, 0.70 for face covering, 0.68 for staple length, 0.54 for neck folds, 0.26 for type, and 0.20 for condition. Repeatability of yearling traits at 2 years was greatest for face covering (0.82), followed by staple length (0.75), body weight (0.71), grease-fleece weight (0.70), clean-fleece weight (0.63), neck folds (0.58), type (0.40), and condition (0.37). Correlations of traits at weaning and one year with those of later ages were roughly similar to the above orders and generally declined as the intervening years increased. The adjustment of weanling and yearling records for important environmental effects had practically no effect on the correlations. Significant positive relationships were found at most ages between staple length and clean-fleece weight (0.55 for yearlings) and between grease-fleece weight and clean-fleece weight (0.72 for yearlings). Weanling and yearling staple length showed significant positive correlations with grease-fleece weight (0.34 and 0.30 with yearling grease-fleece weight). Body weight was significantly correlated with the 3 fleece traits. Body weight, type and condition were significantly correlated with each other. Face covering was practically independent of the other traits. A significant negative correlation (−0.12 for yearlings) was found between neck folds and staple length and a significant positive correlation (0.29 for yearlings) was found between neck folds and grease-fleece weight.

THE INFLUENCE OF ESTROUS CYCLE LENGTH ON BOVINE FERTILITY. N. L. VanDemark and A. N. Moeller, *University of Illinois.*

Using the interval between services by artificial insemination as a measure of estrous cycle length in cows, data on 4885 separate cycles between 1st and 2nd, and 2nd and 3rd services were compiled along with the fertility data for each cycle interval as determined by 180 day non-returns to service. Estrous cycle length was recorded by days up to and including cycles of 72 days. Using 35 days as a maximum period for one cycle, it was found that 82% of the cows had cycles between 18 and 25 days with the mode at 21 days. Definite peaks in cow numbers were shown also at 42 and 63 days indicating the frequency of quiescent or unreported 21 day estrous cycles. An overall fertility level of 49% non-returns to service was found. The fertility levels based on non-returns to service after estrous cycles of 2–17, 18–25, 26–35, 36–50 and 51–72 days were 34, 49, 45, 50, and 54 per cent, respectively. The fertility of cows bred following cycles of 2 to 17 days was significantly lower than the average. The differences from the mean of the fertility of the other groups were not significant.

CARCASS STUDIES ON HOGS OF DIFFERENT BREEDING. Joe V. Whiteman, J. C. Hillier, J. A. Whatley, *Oklahoma A. & M. College.*

Carcass measurements and cut-outs were obtained on 136 hogs from 5 inbred Duroc lines, 4 Duroc single crosses, 3 Duroc three-line crosses, a Landrace-Poland line, a Poland × Duroc crossbred lot, a Minnesota No. 2 × Duroc crossbred lot, and an outbred Duroc lot. The items in the analysis included specific gravity, back fat thickness, carcass length, loin lean area, ham lean area, and percentages of ham, loin, shoulder, belly and primal cuts. In the first test, there were no significant differences among the single cross and outbred Durocs. One inbred line was inferior to the other four in percentage of ham and ham lean area in the second test. Minnesota No. 2 × Duroc carcasses in the third test were longer, had more ham, a higher specific gravity and less backfat than the outbred lot and two single cross Duroc lots. The outbred Durocs had a larger loin lean area and more ham than the single crosses. In the fourth test including 53 carcasses, the Landrace-Polands and the two crossbred lots were significantly superior to the Durocs in 8 out of the 10 items, and similarly the Landrace-

Polands were significantly supperior to the crossbreds in 8 of the items. The line cross Durocs were superior to the outbreds in six items. There were no differences between the single and three-line cross Durocs.

THE INFLUENCE OF TYPE ON FEEDLOT PERFORMANCE AND KILLING QUALITIES OF HEREFORD STEERS. N. B. Willey, O. D. Butler, J. K. Riggs, J. H. Jones, and P. J. Lyerly, *A. & M. College of Texas.*

"Comprest" and "Regular" type Hereford steer calves from the same ranch were compared as to rate and efficiency of gain in the feedlot, followed by slaughter and carcass studies. These calves were fed for a period of 112 days on a ration calculated to promote normal growth. Following this, they received a fattening ration containing about 59 percent concentrates for 173 days. The "Regular" type calves were taller over the top of shoulders, longer of body, greater in depth of chest, and greater in distance from chest floor to ground than were the "Comprest" calves. More total gain was made by the "Regular" type calves and they utilized feed with slightly greater efficiency. The "Regular" type calves cost less per head, but had a greater feeding and marketing cost, because of their greater total feed consumption and shipping cost. The difference between expenses, as calculated in this trial, and the carcass values were in favor of the "Regular" type. The percentages of wholesale cuts were equal in both types, except that of the shank. The percentage of this cut from the "Regular" calves was greater. The estimated percentages of separable fat, lean, and bone were equal in carcasses from the two types. The percent of market weight composed of untrimmed green hide, untrimmed heat, and shanks was greater in the case of the "Comprest" type steers.

Extension Section

G. R. Johnson, *Chairman*

THREE-DIMENSIONAL KODACHROME TRANSPARENCIES AS VISUAL AIDS IN TEACHING ANIMAL HUSBANDRY COURSES. G. Bohstedt, *University of Wisconsin.*

The addition of a third dimension, or a depth dimension, to an ordinary color picture on a screen should have strong appeal to animal and dairy husbandry teachers, especially teachers of courses in judging livestock and meats. Such projected pictures taken with cameras like the recently developed Stereo Realist, and viewed through appropriate spectacles, come nearer showing the actual animal or other object than any system of photography so far perfected. Animals or objects seen from only one angle give a "rounded" aspect, and reveal in a remarkable manner their qualities or faults of symmetry and form. Limitations of this process, such as the factor of distortion in projecting close-ups, are pointed out. The demonstration includes projection of color stereo slides of live animals, and in many cases their corresponding carcasses and cuts of meat as used in the judging and grading of market classes of livestock.

Meats Section

D. C. Brady, *Chairman*

EFFECT OF FATTENING UPON CERTAIN CHARACTERISTICS OF CONNECTIVE TISSUE IN AGED BOVINE. W. E. Batterman, R. W. Bray and P. H. Phillips, *University of Wisconsin.*

This experiment was conducted to determine the effect of fattening on the moisture, ash, fat and collagenic connective tissue content of aged cows. Samples were taken by biopsy from the top round or semimembranosus of U. S. Cutter cows prior to feeding and a similar sample taken from the opposite round at the end of the experiment when the animals were slaughtered. Standard methods of analysis were used for moisture, ash and fat; the collagenic connective tissue was determined by the technique developed by J. L. Hall. The fat content

of muscle increased very rapidly during feeding with a corresponding decrease in moisture. The amount of collagenic connective tissue was significantly decreased, and the total nitrogen of the muscle increased as the cows increased in finish. There was a significant negative correlation between the increase in fat and collagenic connective tissue, and a significant positive correlation between increase in fat and the increase in total nitrogen of the muscle. Tenderness determinations were made by Warner-Bratzler shear on samples prior and after feeding. There was significant improvement on tenderness at the end of feeding evidenced by a lowering of the shear test value. The correlation between the Warner-Bratzler shear readings and the decrease in quantity of collagen was 0.79.

THE FREEZING AND STORAGE OF MEAT IN A HOME STORAGE UNIT. Fred W. Boren and David L. Mackintosh, *Kansas State College.*

Consumer demand for home freezer units has grown tremendously in the past five years, which has resulted in a need for further information relating to the use of these units in the preservation of food. This experiment was designed to determine the rate of freezing of 40, 60, and 120 pounds of ground meat packaged in two-pound packages, and the effect of the addition of these amounts of warm meat upon the temperature of 40, 80, and 60 pounds of stored meat respectively. The power consumption of each cabinet during the freezing and storage period, and the efficiency with which each box operated was observed. Three top opening, single compartment, commercial units were used and designated as A, B, and C. Unit A sharp-froze only 50 pounds of meat, while units B and C sharp-froze approximately 100 pounds. The approximate freezing capacity per cubic foot of storage space for boxes A, B, and C was 6, 9, and 12 pounds respectively. The kilowatt hours required to maintain an empty cabinet at 0° F. is essentially the same as that required to store and maintain from 40 to 180 pounds of meat at 0°F. The power required for storage and maintenance was approximately 0.07 KWH per hour; for freezing it required approximately 0.14 KWH per hour. The addition of from 40 to 120 pounds of warm meat had little effect upon the temperature of the stored meat.

THE YIELD OF EDIBLE MEAT FROM DIFFERENT MARKET CLASSES OF CHICKENS. Paul B. Brown, *University of Illinois.*

Twenty birds from each of five market classes and breeds of chickens; crossbred broilers, from New Hampshire males and Barred Plymouth Rock hens; Rhode Island Red Fryers; White Leghorn light hens; White Plymouth Rock heavy hens, and Columbian light roaster males were slaughtered and the meat separated from the bones by mechanical means. Weights of the birds were obtained as follows: live, New York dressed, clean dressed, inedible offal, bones, giblets, and edible meat. From these weights the percentage of edible meat of the live weight, clean dressed weight and the New York dressed weight was calculated. The percentage of the clean dressed weight of the live weight and the percentage of the New York dressed weight of the live weight were also calculated. The amount of edible meat obtained from the live weight was as follows: broilers, 48.5%; fryers, 48.4%; light hens, 49.0%; heavy hens, 51.1%; and the light roasters, 54.7%; with an average of 50.3% for the five classes. For the percentages of the other calculations, the relationship of the five classes was in the same order and the averages of those calculations are as follows: percent of the clean dressed weight of the live weight, 71.3; percent of the New York dressed weight of the live weight, 90.8; percent of edible meat of the clean dressed weight, 70.5; percent of edible meat of the New York dressed weight, 55.5.

A SURVEY OF FARM MEAT CURING METHODS. C. F. Dunker and O. G. Hankins, *U. S. Department of Agriculture.*

A country-wide survey was made to determine the typical methods used by farmers in curing meat. According to 1315 reports from 45 states, 74 percent of the farmers dry cure without pumping, 16 percent brine cure without pumping, 5 percent pump followed by dry cure, 4 percent pump followed by brine cure, 1 percent pump only. Approximately one-half

of the farmers who dry cure without previous pumping use salt only as the curing agent, the remainder use a commercial or home-prepared mixture. Considering all types of curing, 41 percent use salt only as the curing agent, 26 percent use a commercial mixture, 22 percent use a home-prepared mixture, and 11 percent use miscellaneous methods or were not specific as to type of cure used. The home-prepared mixtures used consisted of a combination of two or more of the following ingredients: salt, brown or white sugar, pepper, and saltpeter, the most common being salt, brown sugar and saltpeter. Commercial mixtures contained various combinations of salt, sugar, condensed wood smoke, spices, meat flavoring, and saltpeter. Brine curers usually cured their meat for 2 days per pound and dry curers for 1½ days per pound. After curing, the meat was usually washed and then smoked from 1 to 30 days, with an average smoking period of 2 to 4 days. After smoking, meat was generally stored in a dry dark room with some air circulation. Packaging consisted in wrapping in paper, in cloth, or hanging without protective covering in the smoke house. Meat was commonly stored up to about 11 months before it was all used.

THE INFLUENCE OF STORAGE TREATMENT ON DETERIORATION IN FROZEN BEEF. Carl Emerson, D. E. Brady, and L. N. Tucker, *University of Missouri.*

Differences attributable to storage treatments were more marked in the case of ground beef than in the case of roasts and steaks when measured by palatability scores, moisture losses and the increase in free amino nitrogen. The differences became increasingly pronounced as the length of storage period increased. Four defrostings of the ground beef during zero storage resulted in a noticeable lowering of the palatability which was not true of 3 defrostings. Those samples defrosted six times were rated as undesirable. The moisture retention qualities of cellulose film, foil, laminates and freezer waxed paper were closely associated with appearance and palatability.

THE RELATION OF CERTAIN FEEDING MANAGEMENT PRACTICES TO THE BIOCHEMISTRY AND QUALITY OF MEAT. Truman Hershberger, Robert Deans, L. E. Kunkle, Paul Gerlaugh, and F. E. Deatherage, *Ohio Agr'l Experiment Station.*

Two groups of ten Hereford feeder steers were put on a 200 day dry lot feeding test with poor quality hay for roughage, ground ear corn, and cod liver oil as the basic ration. This was supplemented with 1½ lbs. soya bean oil meal per day for one group and with 3½ lbs. high quality alfalfa leaf meal for the other group so as to balance the protein intake. The steers on alfalfa leaf supplement gained more rapidly than those on the soya bean oil meal. The carcasses were studied for market grade, juiciness, tenderness at 3 and 15 days *post mortem*, yield of edible lean meat, intramuscular fat, color of fat, vitamin A in the liver, muscle hemoglobin, pH, and alkali insoluble protein. The rate of gain and the carcass weights from the alfalfa fed steers were greater.

THE EFFECTS OF THREE FORMULATIONS OF BENZENE HEXACHLORIDE ON THE FLAVOR OF PORK. James D. Kemp, *University of Illinois.*

Thirty-two hogs of Hampshire, Poland China, and Chester White breeding were divided equally into four groups. Group 1 was not sprayed. Group 2 was sprayed with a 10 percent gamma isomer ethyl methyl ketone solution of benzene hexachloride diluted to 0.125 percent gamma isomer concentration. Group 3 was sprayed with a 99.0 percent pure 15 percent gamma isomer methyl ethyl ketone solution of benzene hexachloride diluted to 0.125 percent gamma isomer concentration. Group 4 was sprayed with 12 percent gamma isomer technical grade wettable powder benzene hexachloride diluted to 0.125 percent gamma isomer concentration. The hogs were slaughtered at intervals of 1, 7, 10, 20, 29, and 41 days after spraying. A loin roast, with an inch of back fat, from each carcass was roasted without seasoning under controlled conditions. A panel of 6 to 8 judges made palatability tests on the roasts. Little or no off-flavor due to benzene hexachloride was detected in any of the roasts from hogs sprayed 7 or more days before slaughter. Little or no off-flavor was detected in roasts from hogs sprayed one day before slaughter with the suspensions made from technical 10 percent gamma isomer

or 15 percent pure gamma isomer benzene hexachloride. A marked off-flavor was detected in roasts sprayed one day before slaughter with a suspension made from 12 percent technical grade gamma isomer wettable powder benzene hexachloride.

THE EFFECT OF HIGH AND LOW FAT CORN ON CARCASS QUALITY IN HOGS. J. G. Moffitt, J. L. Krider, S. W. Terrill and Sleeter Bull, *University of Illinois.*

Two lots of 15 pigs each were self-fed shelled yellow corn and protein supplement on winter rye pasture from an average initial weight of 101 lb. to an average final weight of 226 lb. to study the effect on carcass quality and rate and efficiency of gain of feeding corn containing 4.71% fat and 8.8% crude protein and corn containing 6.40% fat and 11.1% crude protein (analyses on a dry basis). The following averages were obtained for Lot 1 and Lot 2, respectively, from carcass data on the 21 head that were slaughtered as each pig reached approximately 225 lb. in live weight: refractive index 1.4604, 1.4603; iodine number 63.84, 65.81; numerical carcass firmness grade 2.4, 2.2 (2 = medium hard, 3 = medium soft); fat back thickness 4.74 cm., 5.19 cm.; and cold dressing percentage 80.5, 79.6. The average numerical carcass grade was the same for both lots. The higher average iodine number for Lot 2 indicates a greater degree of unsaturation of the fat from hogs fed the higher fat corn but the difference was not statistically significant (odds 10:1). The average daily gains were 1.61 lb. for Lot 1 and 1.58 lb. for Lot 2. The total feed consumed per 100 lb. gain was the same (417 lb.) for both lots. The amount of protein supplement (equal parts of meat and bone scraps, expeller soybean oil meal and dehydrated alfalfa meal with mineral additions) consumed was 40.0 per cwt. gain for Lot 1 but only 29.3 lb. for Lot 2.

ODOR, FLAVOR AND PEROXIDE VALUES AS MEASURES OF RANCIDITY. H. D. Naumann, D. E. Brady, A. Z. Palmer, L. N. Tucker, *University of Missouri.*

A significant relationship was found to exist between odor, flavor and peroxide values as measures of rancidity. Peroxide values were not as closely correlated to one another as were flavor and odor. The degree of unsaturation, storage temperature, effectiveness of the oxygen barrier and length of storage all had an effect on the freezer storage life of pork with the length of storage having the most pronounced effect. Defrosting had a pronounced and immediate effect upon rancidity development but the effect was not progressive and for prolonged storage, defrosting followed by prolonged zero storage resulted in less deterioration than storage at a 10 degrees above zero. Marked individual variation was found between carcasses in their susceptibility to rancidity. Thus the peroxide values associated with a particular level of organoleptic rancidity and the rate of peroxide accumulation varied with the individual as well as the treatment.

PORK FAT CHARACTERISTICS AS RELATED TO DETERIORATION IN FROZEN STORAGE. Z. Palmer, D. E. Brady, H. D. Naumann, L. N. Tucker, *University of Missouri.*

Fat deterioration in frozen pork roasts, chops, and ground pork, both oxidative and hydrolytic, is influenced by storage temperature, length of storage, moisture-vapor wrap efficiency, and the degree of fat saturation. Organoleptic scores on desirability and rancidity of flavor and odor were found to be negatively correlated with initial Iodine values, this relationship being pronounced immediately following the induction period. Differences in efficiency of wrap became increasingly marked with higher temperatures and prolonged storage resulting in decreased palatability as well as higher peroxide and free fatty acid values. The degree of unsaturation in pork fat was influenced by rate of gain, character and percent of fat in the ration, length of time the hogs were fed a ration high in unsaturated fat and final slaughter weight.

VITAMIN LOSSES IN DRIP FROM FROZEN-DEFROSTED BEEF. A. M. Pearson, H. M. Edwards, J. E. Burnside, A. F. Novak, R. S. Glasscock and T. J. Cunha, *University of Florida.*

Rib steaks from a U. S. Good beef carcass were frozen and stored in a home freezer held at 0° F. The steaks were thawed overnight at room temperature and the drip, which exuded from surface of the meat upon thawing, was collected and assayed microbiologically for thiamine, riboflavin, niacin, pantothenic acid, pyridoxine and folic acid. Adjacent steaks were analyzed without thawing, in order to determine the levels of the same vitamins in the meat before thawing. The percentage of each vitamin lost in the drip was calculated. The amount of thiamine, riboflavin, niacin, pyridoxine, pantothenic acid and folic acid in the meat was 1.00, 1.59, 34.81, 3.48, 9.11 and 0.15 gammas per gram, respectively. The drip contained 1.13, 0.74, 62.57, 2.16, 29.63 and 0.08 gammas per milliliter, respectively, of thiamine, riboflavin, niacin, pyridoxine, pantothenic acid and folic acid. The percentage of each vitamin contained in the drip amounted to 12.23 percent of the thiamine, 10.31 percent of the riboflavin, 14.51 percent of the niacin, 9.41 percent of the pyridoxine, 33.26 percent of the pantothenic acid and 8.07 percent of the folic acid.

HISTOLOGIC STUDY OF FRESH AND AGED BEEF RIBEYE (LONGISSIMUS DORSI) AND THE OUTSIDE ROUND (SEMITENDINOSUS) MUSCLES. Hsi Wang, *American Meat Institute Foundation.*

Forty-eight carcasses representing light and heavy weight steers heifers and cows of choice or commercial grade were used in this study. Samples were taken at 0, 14, and 28 days of aging at 35° F. They were fixed in Zenker-formol, processed by the standard celloidin technique with both longitudinal and transverse sections cut at 10 micra. They were stained with Hematoxylin, Weigert's and Van Giesen's for total structural differentiation; with Van Giesen's and Weigert's for histo-chemical determination of collagen and elastin, respectively. Many consistent differences between the two muscles have been observed. Two days after slaughter the *Semitendinosus* muscle contained more collagen and elastin with coarser elastic fibers than did the *Longissimus dorsi* muscle from the corresponding carcasses. Also, the *Semitendinosus* muscle contained thicker muscle fibers but smaller muscle bundles (fasciculi), particularly primary muscle bundles, and less fat than corresponding *Longissimus dorsi* muscles. Muscle fibers of the ribeye were mostly straight and arranged in parallel whereas those of the round were frequently thrown into characteristic waves, the so-called Z-Z orientation. The perimysia in the *Semitendinosus* muscle were more closely spaced, and each was more heavily packed with connective tissue fibers than those of the corresponding ribeye samples.

The middle portion of the *Semitendinosus* muscle consistently showed more autolysis than did either end. During aging the two muscles lost about equal percentages of collagen, but owing to a higher initial collagen content in the *Semitendinosus*, the actual amount of collagen lost was greater in the outside round muscle than in the ribeye.

THE VALUE OF PAPAIN FOR INCREASING LARD YIELD AND FOR IMPROVING TENDERNESS OF COW BEEF. G. H. Wellington and J. I. Miller, *Cornell University.*

A laboratory method for measuring lard yield under conditions similar to open kettle rendering was developed. A commercial enzyme preparation containing Papain and a laboratory-prepared 1% Papain solution were used in comparing untreated with treated samples. Pork fat treated with Papain gave a small (.39%) but significant increase in lard yield using the laboratory method of measurement. This amount of increase in comparison with untreated samples was too small to indicate that such treatment would be economical. The weight of unpressed cracklings was much smaller with the Papain treated samples, but there was no significant difference in the yield of the pressed cracklings. This study indicated that the use of Papain is not practical when an efficient lard press is used following cooking. Observations were made of the effect on tenderness of a commercial Papain product and of Papain N. F. grade when these were applied to one inch boneless rib steaks from a cutter cow carcass. Paired samples were used. Tenderness of the cooked steaks was measured using the Warner Bratzler Shear. In each instance the Papain treated steaks were more tender than the controls. After cooking the treated steaks could be distinguished from the untreated by their appearance. There was disagreement regarding the desirability of the flavor of the treated steaks as compared to the controls.

Nutrition Section

R. H. Grummer, *Chairman*

THE VALUE OF A VITAMIN B_{12} CONCENTRATE FOR BROOD SOWS. G. C. Anderson and A. G. Hogan, *Missouri Agricultural Experiment Station.*

Two separate trials were conducted in dry lot. In Trial I eighteen gilts received Ration 347 from an initial weight of 150 lbs. The ration consisted of: corn 70, tankage 5, soybean oil meal 20, alfalfa meal 2.5, cod liver oil 0.5, complex mineral mixture 2.0. When the gilts weighed 200 lbs. they were divided into three groups. One was continued on No. 347; a second received Ration 348 (No. 347 plus Merck's APF No. 3 to supply 10 mcg. of B_{12} per pound of feed); and a third, Ration 349, containing 15% of fish meal and 2% of fish solubles. The percentage of pigs weaned of those born alive and the average weaning weight per pig were: No. 347, 86.7%, 28 lbs.; No. 348, 100%, 36.2 lbs.; No. 349, 100%, 32.5 lbs. In Trial II fifteen gilts farrowed by sows receiving Ration 347, Trial I, were used. Two groups received Ration 353, which was similar to Ration 347 except the tankage was replaced by soybean oil meal and riboflavin, ca-pantothenate and nicotinic acid were added to the ration. One of these groups received in addition fresh cut green rye. A third group received Ration 354 (No. 353 plus 10 mcg. of B_{12} per pound). The percentage of pigs weaned of those born alive and the average weaning weight per pig were: No. 353, 91.9%, 35.9 lbs.; No. 353 plus rye, 100%, 37.7 lbs. No. 354, 97.5%, 37.7 lbs.

SOME FACTORS AFFECTING THE NUTRITIVE VALUE OF COTTONSEED MEAL FOR SWINE. E. R. Barrick, F. H. Smith, G. Matrone, H. A. Stewart and G. H. Wise, *North Carolina State College.*

Two experiments were conducted to study the effects of various supplements and of different methods of processing on the value of cottonseed meal for growing swine. In the first trial the basal diet consisted of corn 55%, hydraulic process cottonseed meal 37%, alfalfa meal 6%, mineral 2% and riboflavin. The effects of supplementing with A.P.F. concentrate and ferrous sulfate were studied. The diets, their respective daily gain in lbs. and feed consumed per 100 lbs. of gain during a 12-week period were as follows: (1) Basal, 0.24, 1128; (2) Basal+$FeSO_4$, 0.91, 515; (3) Basal+A.P.F., high mortality rate before the close of the experiment makes the data unsuitable for comparison; (4) Basal+$FeSO_4$ and A.P.F., 1.22, 381, and (5) control diet containing meat scraps, 1.58, 378. The results show that iron salts were effective in overcoming gossypol toxicity and that A.P.F. gave an added growth response. The second trial was designed to improve diet (4) by the addition of casein as a source of lysine and to compare a special process cottonseed meal and a standard soybean oil meal with the diet containing hydraulic process cottonseed meal. The diets, their respective daily gains in lbs., and feed consumed per 100 lbs. of gain during an 8-week period were as follows: (a) Hydraulic process cottonseed meal with $FeSO_4$ and A.P.F., 1.30, 369; b) diet (a) with added casein, 1.49, 356; (c) special process cottonseed meal with A.P.F. but no iron salts, 1.84, 319, and (4) expeller process soybean oil meal with A.P.F., 1.63, 333.

THE EFFECTS OF AN APF CONCENTRATE CONTAINING AUREOMYCIN ON THE GROWTH AND WELL-BEING OF YOUNG DAIRY CALVES. E. E. Bartley, F. C. Fountaine and F. W. Atkeson, *Kansas Agricultural Experiment Station.*

The growth response of dairy calves from birth to 42 d. of age on a normal diet supplemented with an APF concentrate containing aureomycin (A fermentation product containing residual aureomycin equivalent to about 5 mg. per g. This material kindly furnished by Dr. T. H. Jukes, Lederle Laboratories, Pearl River, New York.) was compared to growth standards and to control calves fed only a normal diet. Twelve calves representing 4 breeds were used. Starting at random, every other calf born within each breed was selected to receive the supplement. Eight calves were supplemented, 4 served as controls. The supplement was fed daily, by capsule, at the rate of 3 g. per 100 lb. body weight. All calves were fed as follows:

colostrum from birth to 3 d.; at 4 d. whole milk at the daily rate of 1 lb. per 10 lb. body weight; at 7 d. hay and grain; at 21 d. a gradual change over to skimmilk. In 42 d. the 8 supplemented calves gained an average of 30.8 lb., while the 4 controls gained an average of only 18.0 lb. The gain of the supplemented calves, however, was not greater than the expected average gain according to the Ragsdale growth standard which by breed and sex is also 30.8 lb. The controls were considerably below their average expected gain of 32.0 lb. A much lower incidence of scouring was noted in the supplemented calves and they were, on an average, thriftier and in better condition than the controls. In this study the APF concentrate containing aureomycin appears to have enhanced growth by preventing scours.

THE ALLEVIATION OF FLUORINE TOXICOSIS BY MEANS OF CERTAIN ALUMINUM COMPOUNDS. D. E. Becker, J. M. Griffith, C. S. Hobbs and W. H. MacIntire, *Tennessee Agricultural Experiment Station.*

Young rats were fed fluorine (NaF) at levels ranging from 13 to 445 p.p.m. per diet to test the postulate that aluminum compound additions to the diet may exert a mitigating effect on chronic fluorosis. Alumina, aluminum chloride, and aluminum sulphate (18 H_2O) were tested for their ameliorative value. After the rats were fed six weeks, the fluorine content of the combined ash of their tibia and femur bones was used as an index of the degree of fluorine toxicosis. This criterion was utilized since it was observed to vary directly with the level of fluorine intake. The findings indicate that when they were fed to supply equivalent quantities of aluminum, the chloride and the sulphate were of equal value for the alleviation of chronic fluorosis. Whereas, on the same basis the alumina was less effective. When aluminum sulfate was fed at 0.53 percent of the diet, the incidence of fluorine in the bone ash indicated a 45 (range of 30–57) percent diminution of the fluorine effects. At lower levels of supplementation the sulphate was less effective. Dental degradation was less severe in rats that were fed aluminum sulphate at the higher levels of fluorine intake. Mineral balance studies conducted with sheep indicated the aluminum served to inactivate the fluoric ion and to diminish its absorption from the intestinal tract.

THE LEVEL OF COBALT TOLERANCE IN YEARLING SHEEP. D. E. Becker and Sedgwick E. Smith, *Cornell University.*

Data have been secured to determine the level of dietary cobalt tolerated by fattening yearling sheep. Yearling wethers fed a ration of shelled yellow corn, soybean oil meal, and mixed legume hay have been drenched daily with cobalt chloride at levels varying from 10 to 500 mg. of elemental cobalt per centiweight per day for periods up to eight weeks. Results obtained show that levels up to 160 mg. of cobalt per centiweight daily can be tolerated for at least eight weeks without harmful effects. Dosages of 200 to 500 mg. of cobalt per centiweight daily caused a severely depressed appetite and body weight losses; anemia was noted at the higher level. Polycythemia was absent, and blood sugar determinations revealed no significant departure from normal. Endeavors to produce polycythemia in six sheep by daily intravenous injections of cobalt at the rate of 75 mg. of cobalt daily resulted in death of two of the animals; there was no elevation in the hemoglobin level. Pathological studies of the sheep which died of cobalt toxicosis as a result of oral administration showed fatty infiltration of the liver, and slight pulmonary edema and congestion in all cases. In addition, three animals which received the highest cobalt intake also showed petechial to ecchymotic hemorrhages in the small intestine.

THE EFFECT OF AUREOMYCIN ON DIGESTION IN STEERS. M. C. Bell, C. K. Whitehair and W. D. Gallup, *Oklahoma A. and M. College.*

The effect of feeding crystalline aureomycin hydrochloride on digestion and nitrogen retention was determined in balance trials with six steers. Four of the steers received a basal ration of corn, soybean oil meal and prairie hay and two steers received the same ration supplemented with urea. Digestion coefficients were obtained for these rations in a previous experiment in which the steers received all constituents except aureomycin. The daily addition

of 0.6 gms. of aureomycin to these rations produced marked anorexia and diarrhea within 48 to 72 hours. The feeding of aureomycin was discontinued until the steers were back "on feed." Two steers were then fed 0.2 gm. of aureomycin per day for 4 days and these steers showed no anorexia or digestive disturbance. After a standard 10-day preliminary period on the basal rations the aureomycin was added at the rate of 0.2 gm. per day to the rations for four of the steers and collection of urine and feces started immediately. The collection periods consisted of five consecutive 3-day periods. Two of the steers receiving aureomycin developed only mild symptoms of anorexia and diarrhea but a third one had to be removed from the experiment. Digestion coefficients, nitrogen retention, and blood urea values were obtained with the remaining five steers. This level of feeding aureomycin decreased the apparent digestibility of dry matter and crude fiber by as much as 15% and 50% respectively. The most pronounced effect was on the digestibility of crude fiber which would suggest that the aureomycin produced an effect on the cellulytic microorganisms in the gastrointestinal tract.

THE ROLE OF APF AND ANTIBIOTICS IN METABOLISM OF THE RAT. Alex Black and John W. Bratzler, *Pennsylvania State College.*

To test the efficacy of APF and antibiotics in growth of the rat, three groups of 12 weanling animals were fed rations of the same composition except for an APF supplement, the protein of the ration being of vegetable origin. One group of rats received the unsupplemented ration and was paired-fed with another group of littermates receiving the APF supplemented ration, while the third group was also fed the supplemented ration but on an *ad libitum* basis. The supplemented *ad libitum* group was killed at five weeks of age at which time the females had gained an average of 133 grams and had consumed 417 grams of feed while the males gained 216 grams and had eaten 545 grams of feed. The paired-fed animals were killed when the unsupplemented animal of the pair had gained approximately the same as the *ad libitum* group. The paired females required an average of 59 days and 567 grams of the unsupplemented ration to gain 128 grams, while the supplemented pair mates gained 133 grams by this time. The unsupplemented paired males gained an average of 200 grams in 75 days and had consumed 869 grams of feed, while their supplemented pair mates increased 229 grams by this time. The rat is therefore greatly influenced by this supplement as noted by efficiency of gains, the males to a greater extent than the females.

THE EFFECT OF METHOD OF ADMINISTRATION ON THE ABSORPTION AND STORAGE OF VITAMIN A BY DAIRY CALVES. J. T. Blake, N. L. Jacobson, and R. S. Allen, *Iowa State College.*

Previous experiments with young dairy calves fed massive doses of vitamin A in oil indicated that this vitamin is absorbed more rapidly when mixed with milk and fed by nipple feeder than when administered in capsules and that rate of uptake is accelerated further by aqueous dispersion of the vitamin. It seemed desirable, therefore, to determine whether rapid uptake results in greater efficiency of absorption and storage. Twenty-four dairy calves, following depletion of their vitamin A reserves, were divided into two groups, one receiving vitamin A in oil and the other receiving vitamin A oil in aqueous dispersion. These groups were subdivided so that half of the calves received the supplement in milk fed by nipple feeder and the remainder received it in capsules. The supplements were fed to the calves over a six-week period at the rate of 3,000 micrograms of vitamin A daily per 100 pounds body weight. The blood plasma vitamin A values during the supplementation period and the time required for post-supplementation depletion were employed as criteria of the degree of absorption of the vitamin supplements. Results indicate that the factors which favor rapid absorption of vitamin A (aqueous dispersion and administration in milk via nipple feeder) also promote more efficient absorption.

THE SUPPLEMENTARY EFFECT OF TRYPTOPHAN IN SWINE RATIONS CONTAINING MEAT SCRAPS. R. E. Bloss, R. W. Luecke, W. N. McMillen and F. Thorp, Jr., *Michigan State College.*

In the present investigation a basal ration composed of 78.5% ground yellow corn, 20% meat and bone scraps, 1.5% complex mineral mix, vitamins A and D, and liberal amounts of thiamin, riboflavin, pantothenic acid, niacin, pyridoxine, and B_{12} and analyzing 0.09% tryptophan was used. Lot 1 received the basal ration, lot 2 basal plus .02% DL-tryptophan, lot 3 basal plus .06% DL-tryptophan, and lot 4 the basal plus 0.12% DL-tryptophan. In lot 5 the basal ration was altered by substituting solvent soybean oil meal for one-half of the protein supplement, to determine if the soybean oil meal would add sufficient tryptophan to meet the pig's requirement. Lot 6 served as a positive control and the ration contained only solvent soybean oil meal as the protein supplement. After six weeks on experiment the average daily gain in pounds per pig for the period was as follows: Lot (1) 0.39, (2) 0.46, (3) 1.03, (4) 1.09, (5) 0.96, (6) 0.96. The pigs in lots 1 and 2 were uniformly small and showed no external symptoms of a tryptophan deficiency other than slow growth. The results indicate that the meat and bone scraps used in the present experiment did not contain sufficient tryptophan to allow for normal growth.

ANIMAL PROTEIN FACTOR SUPPLEMENTATION OF SMALL GRAIN RATIONS FOR SWINE. J. P. Bowland, S. E. Beacom and L. W. McElroy, *University of Alberta.*

Two A.P.F. supplements: (1) Merck A.P.F. containing 12.5 mg. of vitamin B_{12} per lb., and (2) Lederle A.P.F. number 5 containing vitamin B_{12} and residual aureomycin, were added to the growing and fattening rations of Yorkshire swine. A basal ration of barley and oats supplemented with either all vegetable protein (soybean oil meal, linseed oil meal, alfalfa meal, limestone, iodized salt) or mixed animal-vegetable protein (meat scrap, linseed oil meal, alfalfa meal, limestone, iodized salt) was fed in all trials. A slightly increased rate of gain and efficiency of feed utilization resulted when Merck A.P.F. was added at 50 gm. per 100 lb. of either of the rations. Lederle A.P.F. fed as 0.5 percent of the ration resulted in over 25 percent increase in the rate of gain and a marked increase in the efficiency of gain from weaning to market weight. In two separate trials 0.5 percent Lederle A.P.F. caused greatly increased rate and efficiency of gain when fed to unthrifty weanling pigs over a six week period. There was no difference in hemoglobin levels of any of the A.P.F. supplemented pigs as compared to the controls.

THE SUPPLEMENTARY EFFECT OF B-VITAMINS, APF CONCENTRATES, AND STREPTOMYCIN ON GROWTH OF WEANLING PIGS. J. E. Briggs and W. M. Beeson, *Purdue University.*

In one experiment, riboflavin, niacin, calcium pantothenate were added in various combinations to a 20% protein basal ration of corn, soybean meal, fishmeal, meat and bone scraps, cottonseed meal, alfalfa meal, Lederle's APF, vitamins A and D, and minerals. The average daily gains and feed per 100 lb. gain, respectively, for each lot of ten pigs each (initial weight, 30 lb.) for the first 6 weeks in concrete pens were: (1) Basal −1.33 lb., 278 lb.; (2) Basal +0.8 mg. B_2 per lb. −1.36 lb., 258 lb.; (3) Basal +4.5 mg. calcium pantothenate per lb. −1.36 lb., 258 lb.; (4) Basal +0.8 mg. B_2 +4.5 mg. pantothenic acid +5 mg. niacin 1.47 lb., 253 lb. In another experiment 8 lots of 10 weanling pigs each (initial weight, 36 lb.), were fed different supplements in a 20% protein corn-soybean meal-alfalfa meal ration plus riboflavin, niacin, calcium pantothenate, A and D, and minerals, in concrete pens. The average daily gains and feed per 100 lb. gain obtained for each lot during the first six weeks were: (1) Basal −1.25 lb., 261 lb.; (2) Basal +0.50% Lederle's APF −1.53 lb., 253 lb.; (3) Basal +0.10% Merck's APF −1.33 lb., 239 lb.; (4) Basal +2.0% Fortified dried whey −1.12 lb., 251 lb.; (5) Basal +2.0% Fortified dried whey +0.10% Merck's APF −1.28 lb., 273 lb.; (6) Basal +0.10% Merck's APF +2.5 mg. streptomycin per pound −1.32 lb., 256 lb.; (7) Basal +0.10% Merck's APF +15 mg. streptomycin per pound −1.44 lb., 253 lb. (8) Basal +15 mg. streptomycin per pound (no B_{12} −1.28 lb., 249 lb. The appetites of the supplemented lots, particularly lots 2, 5 and 7, were markedly stimulated over that of the basal lot. Diarrhea was observed more markedly in lot 4. No severe diarrhea was noted in other lots.

THE UTILIZATION OF WHOLE EGG, CASEIN, BLOOD FLOUR AND LINSEED PROTEINS SUPPLEMENTED WITH AMINO ACIDS FOR SWINE. M. J. Brinegar, J. K. Loosli and H. H. Williams. *Cornell University.*

Growth and nitrogen balance techniques were used to study the utilization of several proteins by weanling pigs. The rations contained approximately 10% protein. In one experiment, crude casein supplemented with methionine and a commercial source of dried whole egg which was extracted with ether were highly utilized to approximately the same extent. The utilization (percent of apparently digested nitrogen retained) of these proteins was equal to that reported for swine by Bell *et al.* (J. Nutrition, 40: 551, 1950) using a different source of dried whole egg or soybean protein supplemented with methionine. In another experiment, commercial spray dried whole blood protein supplemented with methionine and isoleucine was utilized as efficiently as the egg protein or supplemented casein used in the pervious experiment. The supplemented blood protein had a biological value of 90 as determined by the Thomas-Mitchell method. In the latter experiment, a different source of commercial dried whole egg which was not extracted with ether had a lower biological value than the blood protein supplemented with methionine and isoleucine. The protein of linseed meal supplemented with lysine, histidine and methionine fed to weanling pigs in another trial was not as efficiently utilized as the supplemented blood protein.

EFFECT OF ANTIBIOTICS AND OTHER GROWTH STIMULATING SUBSTANCES IN THE RATIONS OF GROWING AND FATTENING HOGS. J. H. Brown and Herbert G. Luther, *Arenel Farms and Chas. Pfizer & Co.*

The effect of additions of terramycin, streptomycin, penicillin, and aureomycin in graded levels to hog rations was investigated to determine the minimum quantities required for optimum growth. These tests indicate levels as low as three parts per million of antibiotics supports significant positive growth on a balanced all vegetable ration containing Vitamin B_{12} and also showed comparable superiority over practical rations containing animal protein. At four weeks of age increased growth responses of approximately 40% were obtained and superior performance of the antibiotics supplemented groups was maintained to market weight; although the percent increase over the positive control was not maintained at this high level throughout the test period. Graded levels of antibiotics activity in the form of crudes from antibiotic fermentations were also fed with similar performance. A positive control group containing tankage, meat scraps, and fish meal, as well as a second control group containing fish meal, meat scraps, fish solubles, liver meal, and whey were included for comparison purposes. The effects of feeding these antibiotics on intestinal flora were studied and data on the antibiotics tested are presented. Choline and Inositol supplementations were evaluated, however, these matarials did not improve performance. Stability data on the antibiotics mixed feeds and supplements are presented, indicating in the case of penicillin rapid losses of the antibiotic activity in the high moisture contents of mixed feeds.

THE USE OF AN ARTIFICIAL RUMEN IN STUDYING UREA UTILIZATION BY MICROORGANISMS TAKEN FROM THE PAUNCH OF CATTLE. Wise Burroughs, Carlos Arias, Paul Gerlaugh and R. M. Bethke, *Ohio Agricultural Experimental Station.*

The artificial rumen technique used in this laboratory in studying roughage digestion of cattle feeds was adapted for purposes of studying urea utilization. The chief feature of the artificial rumen technique was the setting up in a laboratory flask the fermentation conditions which resembled as closely as practicable the conditions found in the rumen of cattle. The principal difference between the apparatus as used in roughage digestion trials and that used in urea studies was a larger sized fermentation flask which permitted greater sampling for chemical analysis in following the progress of urea conversion. Urea utilization was based upon disappearance of ammonia originating from urea in which no loss occurred in the total nitrogen

content of the flask. Thus far the method has been applied in assessing the importance of various feed sources of energy and protein upon the utilization of non-protein urea nitrogen. The results confirm and extend other observations that amount of available energy is of major importance in urea utilization involving fermentation. Conventional feed protein also altered urea utilization, the details of which will be discussed.

EFFECT OF AN APF CONCENTRATE CONTAINING AUREOMYCIN ON GESTATING AND LACTATING SWINE. Lawrence E. Carpenter, *The Hormel Institute.*

Fifty-three sows and gilts were divided into two groups: 27 served as controls and were fed good practical type diets during gestation and lactation; the other 26 animals were fed the same diets except that 0.5% of Lederle APF no. 5, lot 30, was added from 49 to 93 days prior to parturition and during the lactation period. Litters from the control sows were fed a creep diet of rolled oats while litters from the test sows were fed rolled oats containing 1% of the APF concentrate. After a 56-day lactation period, the pigs weaned by the control dams averaged 24.9 pounds compared to 36 pounds for the pigs weaned by the test dams. Pigs from litters fed rolled oats containing 2, 4, and 8 grams of aureomycin per 100 pounds during the last 28 days of a 56-day lactation period averaged 33.1, 31.3, and 31.5 pounds at weaning compared to 21.9 pounds for pigs in control litters.

EFFECT OF 3-NITRO 4-HYDROXY PHENYL ARSONIC ACID ON THE GROWTH OF SWINE. Lawrence E. Carpenter, *The Hormel Institute.*

Three tests with weaned pigs were conduted to determine the effect of 3-nitro 4-hydroxy phenyl arsonic acid on growth. The levels tested were 0.005, 0.01, and 0.02%. Growth stimulation was noted in all tests for all levels. The high levels produced toxicity. Studies of the gut contents and feces revealed no effect of the compound on the parasite population. Livers from pigs fed a diet containing 0.005% of the arsenical contained 1.69 micrograms of arsenic as As_2O_3 per gram of fresh tissue, compared to 0.19 microgram in the liver from control animals. When the arsenical was removed from the diet, the arsenic content of the liver returned to normal within seven days.

EFFECT OF VITAMIN B_{12}, APF AND ANTIBIOTICS ON ENTERITIS IN SWINE. D. V. Catron, A. B. Hoerlein, P. C. Bennett, P. W. Cuff, P. G. Homeyer, *Iowa Agricultural Experiment Station.*

Previous work at the Iowa Station indicated that the addition of APF (Lederle lot 26) to well-balanced rations controlled certain types of scours in growing pigs. This experiment was to determine what factor(s) in APF was responsible for controlling the scours. One hundred and twenty-eight weanling pigs were allotted by controlled randomization into eight replicated lots on opposite sides of a farrowing house. After one week on their respective rations, the pigs in the replicated lots on one side were challenged with transmissible gastroenteritis virus. The basal ration was yellow corn, soybean oil meal, dehydrated alfalfa meal, minerals (including trace minerals), vitamins A, D_2, and high levels of riboflavin, niacin and pantothenic acid. Average daily gains and feed required per 100 pounds of gain on similar ration treatment (challenged and unchallenged) from weaning to 100 pounds were as follows: basal, 1.08: 334; vitamin B_{12}, 1.34: 286; B_{12} and aureomycin, 1.49: 272; B_{12} and streptomycin, 1.47: 287; aureomycin, 1.34: 259; streptomycin, 1.33: 282; APF (Lederle lot 26), 1.49: 253; APF (Lederle No. 5), 1.30: 303. Analysis of the data showed that B_{12}, aureomycin or streptomycin significantly increased gains ($P = .01$). There were no significant interactions. APF (lot 26) and APF (No. 5) increased gains over basal at $P = .01$ and $P = .05$ respectively. Scouring indices showed more scouring in basal pigs ($P = .05$) and B_{12} pigs ($P = .01$) before challenging. There were no significant differences in the incidence of scouring between the challenged or unchallenged groups or between ration treatments after challenging.

EFFECT OF DIFFERENT LEVELS OF AUREOMYCIN WITH AND WITHOUT VITAMIN B_{12} ON GROWING-FATTENING SWINE. D. V. Catron, V. C. Speer, H. M. Maddock and R. L. Vohs, *Iowa Agricultural Experiment Station.*

The effects of different levels of aureomycin, with and without vitamin B_{12}, were studied with growing-fattening pigs fed an all-plant basal ration in concrete drylot. One hundred twenty Duroc pigs were allotted to 10 replicated treatments on the basis of previous treatment, weight, age, condition, litter and sex. Five levels of crystalline aureomycin hydrochloride (0, 5, 10, 20, and 40 milligrams), with and without 10 micrograms of vitamin B_{12}, were added per pound of complete ration. The all-plant basal ration consisted of ground yellow corn, blended solvent soybean oil meal, minerals (including trace minerals), vitamins A, D_2, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, choline and folic acid. The pigs were self-fed from an average weight of 36 to 200 pounds. The addition of aureomycin at all levels resulted in significantly greater average daily gains ($P=.01$) over the basal ration. Pigs receiving vitamin B_{12} made significantly greater average daily gains ($P=.01$) than those not receiving vitamin B_{12}. The incidence of scouring, after the first week, was less in those lots receiving aureomycin. There were no significant differences in feed efficiency.

THE EFFECT OF VARIOUS ANTIBIOTICS ON FATTENING LAMBS. R. W. Colby, F. A. Rau and J. C. Miller, *Texas Agricultural Experiment Station.*

Feeding trials studying the effect of aureomycin, penicillin and streptomycin on fattening lambs have been conducted. In the first trial three groups of 6 lambs each were used—Lot I was fed the basal ration; Lot II, basal ration +100 mg. aureomycin daily, orally by capsule; Lot III, basal ration +100 mg. aureomycin + all known B vitamins. Control animals gained 0.52 lbs. per day, while lambs in Lot II lost 0.16 lbs. per day and those in Lot III lost 0.20 lbs. per day. Lambs receiving aureomycin went almost entirely off feed. Penicillin and streptomycin were studied in a second trial. Three groups of 7 lambs each were used—Lot I, basal ration; Lot II, basal ration plus 100 mg. penicillin daily, orally by capsule; Lot III, basal ration plus 100 mg. streptomycin daily, orally by capsule. These two antibiotics were less severe in their effects than aureomycin. The penicillin supplement caused the lambs to go off feed, lose weight, and have diarrhea for almost a week. Following this there was a period of gradual recovery. Their weight was still less than control animals at the end of the test. Streptomycin was the least severe of all three antibiotics in its effect upon the lambs. Weight gains of lambs fed streptomycin were slightly less than control animals. On the basis of these experiments, the use of antibiotics in ruminant rations cannot be recommended.

THE RELATIONSHIP OF VARIOUS BLOOD CONSTITUENTS TO RATE OF GAIN IN BEEF CATTLE. R. W. Colby, J. H. Ware, J. P. Baker and C. M. Lyman, *Texas Agricultural Experiment Station.*

Tests have been made of levels of various constituents in blood of beef calves in order to find any that might be correlated with rate of gain, and thus might serve as a measure of potential rate of gain of a calf, while still at an immature stage. Blood urea, non-protein nitrogen, creatine, creatinine, glucose, and cholesterol have been studied. The mean levels of the following constituents, standard deviation and correlation coefficient with rate of gain are shown. Blood urea $=11.98$ mg. per cent, $s=2.28$, $r=-.55$, non-protein nitrogen $=37.06$ mg. per cent, $s=4.04$, $r=-.019$, creatine $=2.20$ mg. per cent, $s=0.18$, $r=-.22$; creatinine $=1.32$ mg. per cent, $s=0.016$, $r=-.28$; and glucose $=68.2$ mg. per cent, $s=2.25$, $r=-.43$. None of these are correlated with rate of gain to a significant extent. In a test with a limited number of bull calves (15), blood level of cholesterol shows promise. Average level of cholesterol is 195 mg. per cent, $s=23.4$, $r=.98$. This is significant with bulls. No significant correlation was found with heifers on the basis of limited data. These blood levels were found at the end of a 196 day growing period following weaning.

RATIONS FOR SLOW-GROWING (RUNT) PIGS. P. W. Cuff, H. M. Maddock, V. C. Speer, D. V. Catron, *Iowa Agricultural Experiment Station.*

Previous work at the Iowa Station showed that slow-growing "runt" pigs fed a good ration including high levels of B-vitamins plus 1% of an APF concentrate high in antibiotic(s) produced highly satisfactory average daily gains. The purpose of this experiment was to study the factors responsible for the improved growth. Sixty-three "runt" pigs averaging 21 pounds at 72 days of age were equally allotted into nine concrete dry lots. A "runt" pig is tentatively defined as an unthrifty pig weighing less than 20 pounds at 56 days. They were self-fed a basal ration containing 18% crude protein, composed of yellow corn, soybean oil meal, 10% meat and bone scraps, 5% dehydrated alfalfa meal, minerals (including trace minerals) and vitamins A and D_2. The following inclusions were made in the basal ration: skimmilk (hand full fed twice daily); B-vitamins (injected once and fed continuously); APF (Pfizer) and B-vitamins; APF, B-vitamins and thyroprotein; APF only; vitamin B_{12}; aureomycin; vitamin B_{12} and aureomycin. APF significantly ($P = .05$) improved the daily gains. The addition of B-vitamins or vitamin B_{12} did not significantly affect the gains. There was no interaction between APF and B-vitamins or between vitamin B_{12} and aureomycin. Aureomycin significantly ($P < .01$) increased the daily gains. Pigs receiving aureomycin were more uniform in size, more thrifty in appearance and exhibited less scouring than the pigs on the other treatments. The results indicate that slow-growing "runt" pigs will respond to nutritional and antibiotic (aureomycin) therapy.

APF, B_{12}, B_{13}, AND RELATED FACTORS FOR THE PIG. T. J. Cunha, H. M. Edwards, G. B. Meadows, R. H. Benson, A. M. Pearson and R. S. Glasscock, *University of Florida.*

A control ration of corn, peanut meal, minerals (including trace minerals) and vitamins A, D, thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, choline and folic acid was used. Lederle APF, when added to the control ration, increased efficiency of feed utilization, rate of gain, appetite, efficiency of protein utilization, bloom, and smoothness of hair coat. It also prevented occasional scours and a mange-like skin condition (not mange) which occurred on control ration. Lederle APF was alkali-treated to destroy B_{12} and change aureomycin into a substance (s) with an antibiotic effect against certain microorganisms but with no inhibitory effect against the assay organism *staphylococcus aureus.* The data obtained showed that the alkali-treated APF contains a factor(s) which promotes growth and has a sparing effect on B_{12} needs of the pig. B_{12} was shown to increase growth of pigs on the corn-peanut meal ration (these pigs had previously been depleted on the corn-peanut meal ration). A vitamin B_{13} concentrate (from Hiram-Walker & Sons, Inc.) was shown to increase growth rate of pigs in two trials. However, variation existed in the length of time required before B_{13} supplementation began to increase the rate of gain, perhaps indicating that B_{13} is stored by the pig.

EFFECT OF AUREOMYCIN AND OTHER ANTIBIOTICS ON THE PIG. T. J. Cunha, G. B. Meadows, H. M. Edwards, R. F. Sewell, C. B. Shawver, A. M. Pearson and R. S. Glasscock, *University of Florida.*

A control ration of corn, peanut meal, minerals (including trace minerals) and vitamins A, D, thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, choline and folic acid was used. Aureomycin supplementation of this control ration increased rate of growth, efficiency of feed utilization, appetite, bloom and smoothness of hair coats. Aureomycin also prevented periodic scours which occurred with the control pigs. Thus, it was shown that aureomycin is responsible for a great deal of the beneficial effect of the Lederle APF which contains B_{12}, aureomycin, and possibly another factor(s). One percent of one experimental Lederle APF supplement supplied enough aureomycin for the pig since pure aureomycin supplementation in addition gave no further growth response. Aureomycin, streptomycin and penicillin were compared. Penicillin was of no benefit in growth; whereas, streptomycin stimulated growth

to a small extent but not as much as aureomycin which gave by far the greatest response. The responses produced by penicillin and streptomycin as compared with that produced by aureomycin in these pigs showed considerable differences which are in marked contrast with the results obtained with chicks on a corn-soybean diet (Whitehill *et al.*, Proc. Soc. Exp. Biol. & Med. 74: 11, 1950) where these three antibiotics gave about the same growth response. These data indicate that differences may occur with various antibiotics used with different control rations and with different species of animals.

STIMULATION OF GAIN OF SWINE BY COBALT AND APF. W. E. Dinusson, E. W. Klosterman, E. L. Lasley and M. L. Buchanan, *North Dakota Agricultural College.*

Three experiments have demonstrated that additions of cobalt to the basal rations resulted in significantly greater gains with growing fattening pigs. In the initial trial on a basal ration of corn, barley, tankage, linseed meal, ground alfalfa, bonemeal and iodized salt the Duroc pigs (initial average weight, 52 lbs.) made an average daily gain of 1.13 lb. per day for a 98 day feeding period. Additions of cobalt chloride (885 micrograms of cobalt per pound of ration) gave daily gains of 1.34 lb. per day. The use of a trace mineralized salt containing manganese, iodine, cobalt, iron and copper gave average daily gains of 1.44 lb. per day. Two additional trials were conducted using a basal ration of corn, soybean oil meal, dehydrated alfalfa, salt and bonemeal. The Duroc pigs weighed about 36 pounds initially for the second trial and when weighed off experiment at 180 pounds had made the following average daily gains: (1) Basal 1.35 lb. (2) Cobalt ($CoCO_3$ supplying 885 micrograms Co per lb. ration) 1.45 lb. (3) Merck's APF #3 (supplying 9.42 micrograms of B_{12} per lb. of ration) 1.48 lb. and (4) 8% meat scraps 1.43 lb. A third trial was conducted using cross-bred Duroc-Yorkshire pigs initial weights about 21 lbs. For the same procedure and treatments the average daily gains were (1) 1.13 lbs. (2) 1.34 lb. (3) 1.38 lb. and (4) 1.31 lb. respectively. Statistical interpretation of the data shows treatments 2, 3, and 4 gave significantly greater gains than 1 and although the trend is the same in these two experiments the differences in gains for treatments 2, 3, and 4 were not significant. Feed required per pound of gain in these trials was erratic with no apparent advantages for any treatment.

COMPARISON OF HIGH AND LOW PROTEIN CORN AS EVALUATED BY THE BIOLOGICAL VALUE METHOD. F. A. Dobbins, J. L. Krider, T. S. Hamilton and S. W. Terrill, *University of Illinois.*

Six 78-pound Duroc barrows were trio-fed (equal feed) for determinations of the biological values of the protein from three varieties of yellow corn containing 7.7%, 10.8% and 15.8% crude protein (fresh basis). Each of the three rations employed was ground and mixed to contain approximately 7.6% crude protein with corn as the only source of protein. Corn starch was used with the 10.8% and 15.8% protein corn to adjust to the 7.6% protein level. The first and second experimental periods involved the feeding of the corn rations with each member of a trio receiving one of the rations. The rations were interchanged during the second period. Seven-day preliminary and five-day collection periods were used. Daily collections of urine and feces were made and nitrogen determinations were made according to the Kjeldahl method. During the third period a nitrogen-free ration was fed to all pigs to determine the amount of nitrogen from body origin in the feces and urine. A ten-day preliminary and five-day collection period were used. Four biological values based on growth were calculated for each of the three corns. The average biological values for protein (nitrogen) were 56.4 for the 7.7% protein corn; 47.3 for the 10.8% protein corn; and 46.5 for the 15.8% protein corn.

THIAMIN DEFICIENCY IN THE LAMB. Harold H. Draper and B. Connor Johnson, *University of Illinois.*

Six crossbred lambs, 24 to 48 hours old, were fed a "synthetic milk" diet constituted to resemble cow's milk. This diet contained 30% casein, 30% lard, 34% cerelose and 6% minerals on a dry matter basis, plus water-soluble and fat-soluble vitamins. After dilution to 13% solids the "milk" was homogenized and pasteurized. Thiamin was deleted from the diet of

four lambs (negative controls) but was included in that of the other two (positive controls). Sulfathalidine was fed to all the animals at a rate of 3 grams per liter of "milk." The four lambs fed the thiamin-deficient diet developed anorexia and lost weight after three weeks on experiment. In about four weeks they exhibited convulsions of the type considered characteristic of thiamin deficiency in other species. Opisthotonus and bradycardia were evident. Analysis of urine from the negative controls showed a much decreased excretion of thiamin and an increased concentration of pyruvic acid. Two deficient lambs were given thiamin hydrochloride by intramuscular injection and recovered rapidly from the spasms or anorexia. Histopathological examination of the other two deficient animals failed to reveal any evidence of nerve degeneration or cardiac enlargement. The two lambs receiving thaimin in the diet grew at rates of .43 and .35 lb. per day over their respective experimental periods of five and six weeks. The appearance of these animals was considered normal. The results of this experiment demonstrate that thiamin is an essential nutrient for the lamb.

SPECIAL SOLVENT COTTONSEED MEAL WITH AND WITHOUT APF AND STREPTOMYCIN AS A PROTEIN SUPPLEMENT FOR PIGS FED IN DRYLOT. I. A. Dyer, A. E. Cullison and W. J. Hays, *University of Georgia.*

Seven groups of 9 weanling Duroc and Poland China pigs each were self-fed in drylot to an average final weight of 100 pounds. All rations contained 20% crude protein and were fortified with vitamins A, D, riboflavin, niacin, pantothenic acid and choline. Rations 1–7 respectively were composed as follows: (1) 71% ground corn, 27% meat and bone scraps and 2% mineral mixture; (2) 63% ground corn, 35% solvent cottonseed meal and 2% mineral mixture; (3) same as 2 plus 36g. "APF" (12.5 mg. B_{12} activity per pound) per 100 pounds feed; (4) 65% ground corn, 11% solvent cottonseed meal, 11% solvent soybean oil meal, 11% peanut oil meal and 2% mineral mixture; (5) same as 4 plus 36 g. "APF" per 100 pounds feed; (6) same as 3 plus 2 g. streptomycin (38.7% streptomycin base content) per 100 pounds feed; (7) 64% ground corn, 17% solvent cottonseed meal, 17% solvent soybean oil meal and 2% mineral mixture. The average daily gains of pigs in lots 1–7 were: .68, .84, .91, 1.23, 1.34, 1.33 and 1.61 pounds respectively. Pigs in lots 2 and 3 exhibited no symptoms commonly associated with cottonseed meal poisoning however, some of the pigs in these two lots showed severe dermatitis as well as bleaching of the hair coats. The level of B_{12} activity fed had no apparent effect on either dermatitis or bleaching of the hair coats.

THE NUTRITION VALUE OF SOME TURKISH SUBSTITUTE FEEDS. Isfendiyar Esat-Kadaster, *University of Ankara.*

The digestible crude protein, crude fat, N-free extract and crude cellulose were determined as follows on sheep for the following substitute feeds used in winter feeding in Turkey: Astragallus, two samples—5.0, 0.1, 18.3, 23.9; Thorny-grass, one sample—5.8, 1.4, 18.7, 14.0; Phragmites, three samples—6.4, 1.1, 16.5, 12.3; Thypha, two samples—0.1, 0.7, 8.6, 6.8; Mistletoe, one sample—7.8, 1.7, 29.0, 5.3. Starch values for these feeds were 21.7, 18.5, 20.7, 2.5 and 30.6, respectively.

A PROPOSED GROWTH CURVE FOR NURSING DUROC PIGS RAISED IN DRYLOT. R. P. Forshaw, H. M. Maddock, P. G. Homeyer and D. V. Catron, *Iowa Agricultural Experiment Station.*

Based on 1296 Duroc pigs from 191 litters farrowed by sows maintained on dirt or concrete dry lot during gestation and on concrete during lactation, four growth curves are presented. The rations fed the sows were those being studied to determine the effects of nutrition during gestation and lactation upon the livability and growth of nursing pigs. The individual pigs were weighed at birth and at weekly intervals until weaned (56 days). The average weaning weight was 28.09 ± 8.08 pounds, and the range was 4.5 to 50.0 pounds. Growth curves determined by mean weekly weights are presented for four groups of pigs, namely: (1) for all pigs in the study; (2) for the poorest doing one third of the pigs, i.e., those weighing 24.5 pounds or less at weaning; (3) for the middle one third of the pigs, i. e., those

weighing from 24.51 to 32.00 pounds at weaning; and (4) for the best doing one third of the pigs, i.e., those weighing 32.01 pounds and over at weaning. The inclusion of the standard deviation with each value used in the construction of the curves gives a measure of the variability of the populations studied at each weigh day.

CRITERIA FOR CONSIDERING A BACTERIUM ISOLATED FROM THE RUMEN AS A BONA FIDE RUMEN ORGANISM. L. S. Gall and C. N. Huhtanen, *National Dairy Research Laboratories.*

Not all bacteria present in the rumen are true rumen organisms. Contamination of the rumen is constantly occurring from outside sources. It would seem that the real measure of a true rumen bacterium is one which can establish and maintain itself in the rumen. Since there are about 100 billion bacteria per gram of rumen contents, only those organisms present in one million per gram (or not outnumbered by more than 1 to 100,000 by other bacteria) are considered to be significant. Since the rumen is an anaerobic organ, it would seem that an organism must be able to carry on an anaerobic metabolism in order to thrive there. These considerations substantiated by experimental experience are the basis for the following criteria for judging a true rumen bacterium: 1. The bacterium must be anaerobic. 2. The bacterium must be demonstrated to be present in at least one million per gram of rumen contents. 3. The bacterium must be isolated repeatedly under these conditions. At least 10 isolations of the same pure "type" culture, as shown by selected screen tests, are considered minimum. 4. The bacterium must be isolated from the animals in at least two different geographical localities. 5. The bacterium must produce end-products, from material commonly found in ruminant rations, compatible with those found in the rumen, or produce end-products which can be metabolized by other rumen bacteria to end-products found in the rumen. All five of these conditions should be met before a bacterium is accepted as a true rumen bacterium.

POSSIBLE EFFECT OF UREA AND SOURCE OF PROTEIN SUPPLEMENT ON VITAMIN A UTILIZATION BY SHEEP. Willis D. Gallup, H. M. Briggs, L. S. Pope and James Tucker, *Oklahoma Agricultural Experiment Station.*

Lambs were fed a low-carotene ration until partially depleted in their stores of vitamin A as shown by decreased blood values and low amounts of vitamin A in the livers of a few slaughtered animals. They were then separated into two groups, one group being given 50 and the other 500 i.u. of vitamin A per kg. live weight, daily, as codliver oil. Within each group, 8 lambs received cottonseed meal as a protein supplement and 8 comparable lambs received soybean oil meal. Half of the lambs within each group of eight received urea as a substitute for part of the oil meal nitrogen. Vitamin A in the blood was determined at frequent intervals and after 90 days all the lambs were slaughtered. Livers were saved for vitamin A determinations. In two further experiments conducted in a similar manner with lambs and ewes, prairie hay and a carotene concentrate were used in the experimental rations to supply 8 and 10 times minimum carotene requirements. Results of the blood and liver analyses provided evidence that urea was without effect on carotene or vitamin A utilization. Although there were marked individual variations, the trend of results indicated greater storage of vitamin A in the liver when cottonseed meal was fed than when soybean oil meal was the protein supplement.

THE VALUE OF ELEMENTAL SULFUR IN A METHIONINE DEFICIENT SHEEP RATION. U. S. Garrigus, H. H. Mitchell, W. H. Hale, J. S. Albin, *University of Illinois.*

Black-faced, grade, western, wether lambs weighing from 54 to 86 pounds were grouped into ten trios. The lambs (within trios) were selected for similar weights, body conformation, condition, and wool covering. At the start of the fourteen-week feeding period, patches of wool were shorn from the left shoulder, left side, left thigh, back and rump. The number one lambs in each trio were fed a basal ration planned to be low in sulfur-bearing amino acids, number two lambs in each trio were fed the basal ration supplemented with one-half percent elemental sulfur, while the number three lambs of each trio received the basal ration supple-

mented with one-half percent methionine. Members of a trio were individually fed equal feed. The lambs were weighed biweekly. Using Student's method for analysis of paired data the average differences in gains between number one lambs and number two lambs, while in favor of the number twos, was not significant. The average difference in gains between ones and threes was highly significant (one percent level). The weight of wool produced by the number two and number three lambs was highly significantly greater (one percent level) than that produced by the number one lambs. The length of wool produced by the number two lambs was significantly greater (five percent level) than that produced by the number one lambs while the length of wool produced by the number three lambs was highly significantly greater (one percent level) than that produced by the number one lambs.

PROTEIN EFFICIENCY OF CORN BY-PRODUCTS AND OTHER PROTEIN FEEDS FOR SWINE GROWTH. H. B. Geurin, J. A. Hoefer and W. M. Beeson, *Purdue University.*

The quality of protein in corn oil meal, corn steep water solubles, soybean oil meal, tankage and corn gluten meal was (basically) determined with weanling pigs by using a modification of the Osborne *et al.* (1919) protein efficiency method. The protein efficiency was expressed as pounds gained per pound of protein consumed. Semipurified experimental rations containing a single source of test protein in an amount sufficient to supply 11 percent protein were used. The crude fiber and crude fat levels were equalized in all rations by adding corn fiber and corn oil when necessary. In the first trial dried whole egg was compared with corn oil meal and corn steep water solubles. The respective average daily gains were 1.19, 0.98 and −0.05 pounds while the protein efficiency values were 2.35, 2.14 and −0.15. In the second trial dried skim milk was compared with corn oil meal, soybean oil meal and a protein mixture containing equal parts of corn solubles and soybean oil meal. The average daily gains were 1.44, 1.13, 1.16 and 0.66 pounds respectively. Likewise, the protein efficiency values were 2.42, 2.62, 2.18 and 1.71. A third trial was also conducted in which dried skim milk was compared with corn oil meal, tankage and corn gluten meal. The pigs gained respectively 1.57, 1.32, 0.87 and 0.59 pounds per day. Comparable protein efficiency values were 2.64, 2.51, 1.65 and 1.25.

UREA AS A PROTEIN SUBSTITUTE FOR STEERS FED CITRUS MOLASSES. R. S. Glasscock, H. E. Guilford, T. J. Cunha and A. M. Pearson, *University of Florida.*

Eight pairs of steers were fed citrus molasses and western prairie hay. Urea was fed to six pairs of steers as a protein substitute. The other two pairs were used as controls and fed only prairie hay and citrus molasses. For 70 days steers consumed (controlled feeding) 5.0 pounds of molasses and an average of 4.34 pounds of prairie hay each daily. The steers were supplemented with urea at two levels: 63.76 and 127.52 grams each daily (equivalent to nitrogen in one and two pounds of cottonseed meal respectively). Weight change of steers was not significantly different at these two levels of urea supplementation which resulted in an average daily loss of 0.16 pounds per steer as compared with an average loss of 0.91 pounds for the controls. With hay then fed free-choice, following the initial 70 days, and molasses fed at the constant 5.0 pound level, the steers that received urea consumed 11.1 pounds of hay each daily and made an average daily gain of 0.75 pounds. The controls ate an average of only 4.87 pounds of hay and showed an average daily loss of 0.60 pounds each. Urea supplementation increased appetite.

BEHAVIOR OF RADIOCALCIUM IN THE RAT AND THE CASTRATED MALE BOVINE AS AFFECTED BY THE DIETARY CALCIUM LEVEL. Sam L. Hansard, C. L. Comar, M. P. Plumlee, S. L. Hood and C. S. Hobbs, *Tennessee Agricultural Experiment Station.*

Absorption, excretion and tissue distribution of soluble radiocalcium administered as a single dose was studied in the following experiments: (1) Rats reared on nutritionally adequate diets but levels of 0.1, 0.3, 0.5, and 1.0 percent calcium. (2) Oral administration to 2 yearling steers on high, 1 on normal, and 1 on low calcium. (3) Intravenous administration to

one yearling steer on low calcium. The following observations and conclusion were made: *Rats.* (1) The lower the level of dietary calcium intake, the higher was the percentage retention. (2) At the lowest level of calcium intake, 92 percent of the calcium excreted was derived from skeletal stores. Values for the higher levels were 35, 26, and 16, percent respectively. (3) Epiphysis, jawbone and vertebra showed highest laydown, especially at lower dietary calcium levels. (4) *Steers:* After a 7 day balance period, 25 to 30 percent of the radiocalcium administered orally to steers was retained, as compared to 40 to 60 percent for rats. (5) Relative accumulation of calcium in skeletal and soft tissues was essentially the same for steers as for rats. A maximum of 0.85 percent of the orally administered radiocalcium was found in the blood at 26 to 30 hours; this value declined to 0.10 percent at 120 hours. (6) Following intravenous administration, 29 percent of the dose was found in the blood at 5 minutes, and approximately 0.8 percent at 35 hours; 85 percent of the dose was retained at the end of a 7 day period. There appeared to be a pickup in the reticulo-endothelial system which indicated the probable formation of an aggregate state in the blood.

METABOLISM UNITS FOR LARGE ANIMAL BALANCE EXPERIMENTS USING RADIOISOTOPES. Sam L. Hansard, Charles S. Hobbs, C. L. Comar and M. P. Plumlee, *Tennessee Agricultural Experiment Station.*

The widespread interest in radioisotope usage, and the introduction of radioisotope labeled elements and compounds into the realm of nutritional experimentation has increased the need for development of improved equipment, and techniques for conducting balance studies with large animals. The separation of the urine and feces eliminated by male and female must be complete and quantitative, and area and animal contamination from excreta minimized. Metabolism units of simple design and operation have been designed, constructed and/or adapted that will fulfill the above conditions and effect the satisfactory quantitative separation of urine and feces eliminated by either (1) steers or heifers, (2) ewes or wethers and (3) boars or gilts. The unit for each species includes an adjustable metabolism stall, equipment and facilities for quantitative separate collection of urine and feces, sampling, feeding, watering, shielding, and animal immobilization for dosing or bleeding. A detailed discussion of the design and operation of the swine metabolism unit will be presented. The novel feature of this unit is its adaptability and the reinforced restraining device which consists of two charged wires from a battery electric fence unit adjustable inward across the rear opening of the stall at the hock-ham level, that restrains the animal without discomfort and discourages the animal from stepping back into the feces collection pan.

THE EFFECT OF FEEDING VARIOUS LEVELS OF ENERGY, PROTEIN AND PHOSPHORUS TO RANGE SHEEP. Lorin E. Harris, C. Wayne Cook, L. A. Stoddart and L. L. Madsen, *Utah State Agricultural College.*

Three levels of energy (barley), three levels of protein (soybean oil meal), and three levels of monosodium phosphate were fed to six age groups of sheep in a factorially designed experiment. The 162 ewes were fed every day in individual pens. During the day they were herded on the open range. The results were measured in terms of live-weight gains, general health, fleece weights, lamb crop, and blood analyses. The protein supplement increased the lamb crop, amount of wool produced, weight, and health of the ewes. The phosphorus supplement increased the lamb crop, maintenance of weight and health of the ewes. The energy supplement alone was of little value. Evidence is presented that a range supplement for sheep on the saltbush winter range should contain at least a protein and phosphorus supplement along with sufficient energy to satisfy the nutritive requirements of the ewe. A method of feeding sheep individually on the range was developed. This opens the way for extensive range nutrition experiments with sheep.

REPRODUCTION AND LACTATION PERFORMANCE OF SOWS FED VITAMIN AND APF CONCENTRATES. A. A. Heidebrecht, O. B. Ross, R. W. MacVicar, and C. K. Whitehair, *Oklahoma A. and M. College.*

The purpose of this experiment was to study the reproduction and lactation performance

of sows fed corn-soybean meal rations supplemented with certain B-vitamins and APF concentrates. Twenty-four gilts and eight sows that had been confined since weaning in concrete lots and fed a corn-soybean meal ration comparable to the basal ration given below were divided into 4 lots at time of breeding. The basal ration consisted of ground yellow corn, 82.0%; expeller soybean meal, 11.0%; alfalfa meal, 5%; and steamed bonemeal, 1.5%. The rations fed the various lots during gestation and lactation were: Lot 1, basal; lot 2, basal +riboflavin, nicotinic acid, and calcium pantothenate; lot 3, basal+riboflavin, nicotinic acid, calcium pantothenate+an APF supplement containing 12.5 mg. B_{12} per lb.; Lot 4, basal+riboflavin, nicotinic acid, calcium pantothenate+an APF supplement containing aureomycin. During the course of the experiment, an infectious type of digestive disturbance was encountered. It was assumed that all animals were abnormal experimental subjects. The average percent of pigs weaned and average weaning weight per pig, respectively, were: Lot 1, 39.2%, 17.9 lbs.; lot 2, 78.3%, 18.9 lbs.; lot 3, 34.6%, 23.1 lbs.; lot 4, 73.4%, 27.4 lbs. Diarrhea was evident in sows and pigs in all lots. The diarrhea observed in sows and pigs of lot 4 was less severe than in the other lots. Although the percentage of pigs weaned in lot 2 was considerably higher than that of lots 1 and 3, many died shortly after weaning. It would appear that the APF concentrate containing aureomycin afforded considerable protection to sows and pigs exposed to an infectious type of enteritis.

THE PERFORMANCE OF RUMEN INOCULATED CALVES FED A HIGH ROUGHAGE RATION WITH AND WITHOUT A.P.F. SUPPLEMENT. J. W. Hibbs and W. D. Pounden, *Ohio Agricultural Experiment Station.*

Twenty-four Jersey calves were fed free choice after the colostrum feeding period to 12 weeks of age on a high roughage, all vegetable protein mixture of 48 parts coarsely ground hay (½ timothy and ½ alfalfa), 6 parts alfalfa meal and 12 parts of 14.5% protein grain concentrate mixture consisting of corn, oats, bran, soybean oil meal and salt. The complete mixture contained approximately 14.5% protein and 20.0 micrograms of carotenoids per gram. One-half of the calves were fed whole milk for 7 weeks (total 271 lbs. per calf) and the other half for 9 weeks (total 311 lbs. per calf). All calves were rumen inoculated with cud material from older cows at the end of the first week and weekly thereafter for 6 weeks. Twelve calves, 6 of which were fed whole milk for 7 weeks and the other 6 for 9 weeks, were given an A.P.F. supplement containing 12.5 mg. of vitamin B_{12} per lb. (supplied by Merck and Co.) at the rate of 1.3 grams (35.8 micrograms of vitamin B_{12}) per day, added to the milk during the milk feeding period except during the last week of the milk feeding period. Beginning one week before the end of the milk feeding period and continuing to 12 weeks of age 1.3 grams of the A.P.F. supplement were included with each pound of the mixture. Twelve similarly fed control calves were given no A.P.F. supplement. No significant difference in the performance of the calves was noted which could be attributed to the A.P.F. supplement.

THE EFFECT OF FEEDING VARYING LEVELS OF FLUORINE ON CATTLE. C. S. Hobbs, S. L. Hansard, E. R. Barrick, Dennis Sikes, J. L. West, W. H. MacIntire, R. P. Moorman and J. M. Griffith, *Tennessee Agricultural Experiment Station.*

Nine lots with three yearling Hereford heifers per lot were put on an experiment on March 1, 1948 to determine the level of fluorosis in cattle. The heifers have been fed individually a basal ration of lespedeza hay, ground corn, and cottonseed meal. Each animal has received the same amount of concentrates daily, but the lespedeza hay has been fed according to appetites. Lot 1 received the basal ration which contained from 5 to 10 p.p.m. (parts per million) of fluorine. Sodium fluoride was added to the concentrate mixture of lots 2 through 8 to supply the following added amounts of fluorine to their total ration, respectively 10, 20, 30, 40, 50, 70 and 100 p.p.m. These heifers were bred as yearlings. From a study of the data including weight gains, feed records, periodic examination of the cattle for symptoms reported in the literature as indications of fluorosis (especially the teeth), fluorine analysis of feeds, urine, bones (some bone biopsies). After two years of dry lot feeding the teeth of animals receiving rations containing approximately 15 to 30 p.p.m. of fluorine show staining and

markings; 30 to 40 p.p.m. of fluorine show mottling, caries and some wear, 40 to 50 p.p.m. of fluorine show erosion, mottling, pitting and there are effects on weight gains. At higher levels of fluorine feeding all the effects on cattle are more pronounced.

MORE EFFICIENT DESIGN OF SWINE FEEDING EXPERIMENTS. Paul G. Homeyer, Helen M. Maddock and Damon V. Catron. *Iowa Agricultural Experiment Station.*

The efficient design of swine feeding trials in general depends upon such factors as: (1) the selection of pigs to be used and their allotment; (2) the number of pigs assigned per lot and the number of replicate lots on each ration; (3) the selection of rations; (4) the method of feeding; (5) the length of feeding period; and (6) what measurements are made. In any specific feeding trial the objectives and the resources available will of course influence the decisions with respect to the above factors. Although the importance of these and other factors is generally recognized; however, the consequences of the design and experimental techniques used are not always fully understood or appreciated. The object of this paper is to briefly consider the first three factors, indicating some of the consequences of the decisions reached with respect to these factors. Experimental results of several feeding trials at this station and others reported in the literature are used to estimate the relative importance of the factors discussed and the relative efficiencies of different designs. Adjustments for variation attributed to continuous variables such as age and original weight can usually be made most efficiently by proper statistical procedures. Factors such as litter and previous management should be taken care of in the design. The necessity in some cases and advantages in general of using two or more lots per ration are pointed out. The advantages of factorial experiments, in the selection of the treatments, are given and illustrated.

INFLUENCE OF VARYING LEVELS OF MOLYBDENUM UPON GROWTH AND HEMOGLOBIN OF RATS. Max A. Jeter and George K. Davis, *Florida Agricultural Experiment Station.*

Two experiments have been conducted with weanling rats to determine the effects of molybdenum. In the first experiment, a basal ration of mineralized dried whole milk and sugar was fed to two groups with Cu added as $CuSO_4 \cdot 5H_2O$ at the rate of 20 p.p.m. One group received Mo added as $Na_2MoO_4 \cdot 2H_2O$ at the rate of 80 p.p.m. There was no significant difference between the growth rates or hemoglobin at the end of 11 weeks. No signs of copper deficiency or molybdenum toxicity were apparent. In the second experiment, 32 weanling rats were divided into four lots and were fed the same basal ration as in the first experiment. Cu was added to the basal ration at the rate of 5 p.p.m. Mo was added to the ration for the respective lots as follows: 0 p.p.m., 20 p.p.m., 80 p.p.m., 140 p.p.m. The growth rate was retarded in all groups receiving Mo with the retardation in the lot receiving 140 p.p.m. being highly significant. Hemoglobin was variable in the last experiment.

GROWTH PROMOTING EFFECTS OF AUREOMYCIN AND OTHER SUPPLEMENTS. T. H. Jukes and E. L. R. Stokstad, *Lederle Laboratories.*

The effects of adding small amounts of aureomycin and other supplements to the diet were studied with various species. At suboptimal levels of vitamin B_{12}, the growth response was found to be enhanced by aureomycin more markedly than was the case at higher levels of B_{12} in some experiments, however this effect was not observed consistently. The effect of aureomycin on the survival of young rats which were deficient in vitamin B_{12} was studied. No effect of aureomycin on the thyroid gland of young rats was observed in experiments in which thyroid size and uptake of radio-iodine were measured.

THE RELATION OF THE STAGE OF DEVELOPMENT OF THE EMBRYO TO THE PHOSPHORUS CONTENT OF THE BLOOD OF THE EWE. T. B. Keith, R. F. Johnson, W. H. Harvey, A. W. Wiese and C. W. Hickman, *University of Idaho.*

Data on the phosphorus levels of the blood of ewes taken at definite intervals before and after lambing have been summarized to study the effect of the development of the embryo on the phosphorus content of the blood of the ewe. Regression coefficients indicate that a depression of the phosphorus level takes place during the early portion of the lactation period immediately following the birth of the lamb and continues for a period of 4 to 6 weeks after which there is a gradual increase to a higher level.

THE EFFECT OF METHIONINE SUPPLEMENTATION UPON THE UTILIZATION OF PEA AND ALFALFA PROTEINS BY SHEEP. Earle W. Klosterman, D. W. Bolin, W. E. Dinusson and Earl L. Lasley, *North Dakota Agricultural College.*

Two double reversal nitrogen balance experiments have been conducted. In one study eight pregnant, purebred Shropshire ewes were fed two levels of protein with and without methionine supplementation. The biological value of the protein in a ration consisting of grass hay, dried beet pulp, corn sugar and minerals (6.87% protein, dry basis) was not improved by the addition of methionine. The ewes, however, remained in positive nitrogen balance on this ration. The biological value of the protein in these feeds with field peas added to supply a 10.83% protein ration was improved by the addition of approximately 0.1% methionine. In the second experiment mature Hampshire ewes were fed rations of wheat straw, cane molasses, corn sugar, minerals and either field peas or dehydrated alfalfa to supply approximately 11% total protein. In this experiment methionine improved the biological value of the pea ration when fed to three ewes but did not for a fourth ewe due to an unusually high urinary nitrogen excretion during the period of pea plus methionine feeding. The utilization of protein in the alfalfa ration was significantly improved by the addition of methionine. When all the biological values obtained were adjusted by regression to a constant protein intake there was a significant difference between rations supplemented with methionine and those not supplemented. The cystine and methionine content of the rations, feces and urine were determined microbiologically. These analyses showed that the supplemental methionine was either completely utilized or deaminized inasmuch as the methionine content of the feces was approximately the same whether or not the ewes received the methionine supplement. No measurable amount of methionine was found in the urine.

THE SULPHUR DIOXIDE PRESERVATION OF GRASS SILAGE. C. B. Knodt, *Pennsylvania State College.*

Grass silage has been prepared by the use of five pounds of sulphur dioxide per ton of green material. Two similar silos were filled simultaneously with 40 tons each of comparable material prepared from timothy-red clover. One silo was filled with 200 pounds of hominy as a control and the other with five pounds of sulphur dioxide per ton of green material respectively. The sulphur dioxide treated silage contained 3 times as much carotene and was more palatable when fed three to five months after preparation. Two comparable groups of 10 cows each fed 60 pounds of the respective silages per day, produced similar amounts of milk and made similar gains in body weight during a 56 days feeding period. A number of cows also consumed in excess of 80 pounds of the sulphur dioxide treated silage per day without any apparent ill effects. The amount of surface spoilage on the 2 silos was similar but other work indicates that sulphur dioxide may decrease greatly the extent of such spoilage. On the basis of palatability, ease of handling, feeding value of silage preserved with it and low cost, it appears that sulphur dioxide may be of value in the preservation of grass silage.

AMMONIATED CANE MOLASSES IN THE RATIONS OF DAIRY CALVES. C. B. Knodt, J. B. Williams and John Brumbaugh, *Pennsylvania State College.*

A series of trials have been conducted using various types of ammoniated cane molasses in the rations of dairy calves in tests for palatability, gains in body weight and height at the withers. The ammoniated molasses was included at a level of 10 percent in some rations at

a rate of feeding of 6 pounds of grain ration per day to calves 14 to 16 weeks of age without any effect upon palatability. It also appears that the nitrogen in the ammoniated molasses will replace up to two-thirds of the nitrogen in soybean oil meal in these rations when soybean oil meal was fed at a 10 percent level to dairy calves. Similarly, on the basis of 4 groups of 6 calves each with 3 different types of ammoniated molasses and a control group, it would appear that normal growth can be obtained in calves receiving 10 percent of these products in replacement of an equivalent amount of protein from crushed oats and soybean oil meal. It also appears that the ammoniation of cane molasses and similar products may prove to be valuable sources of nitrogen for dairy cattle. The cooperation of the Commercial Solvents Corporation is acknowledged and appreciated.

EFFECT OF PHYSICAL CHARACTER OF FEED ON COMPOSITION OF EWES MILK. R. P. Kuhn, J. S. Hughes, and R. F. Cox, *Kansas State College.*

Results from a number of laboratories indicate that when normal rumination is reduced in a lactating dairy cow, either by reducing the percent of roughage in the ration or by grinding the roughage portion of the ration, the percent of fat in the milk is reduced and the Reichert-Meissl number of the fat is lowered. This experiment was undertaken to see if lactating ewes would respond in the same way to the lack of normal rumination resulting from grinding the roughage portion of the ration. Four lactating ewes were maintained nine weeks on a ration of corn, oats, bran and alfalfa hay. The alfalfa hay was ground and pelleted in the ration of two of the ewes. These two ewes ruminated very little after they were on the ration a few days. Milk samples were taken at weekly intervals. The average final fat content of the milk from ewes receiving the long hay was 8.7 .That from ewes receiving the pelleted hay was 8.0. The average Reichert-Meissl numbers for these samples of milk were 28.4 and 26.9. These results show no marked effect from lack of rumination on the composition of ewes' milk as was found with cows' milk.

APF SUPPLEMENTS IN RATIONS FOR GROWING PIGS. J. F. Lasley, G. C. Anderson, A. G. Hogan, *Missouri Agricultural Experiment Station.*

The pigs were in dry lot from birth, averaged 60 pounds in weight, were divided into 9 lots of 10 pigs each and self fed in dry lot for a period of 50 days. The basal ration consisted of: yellow corn, soybean oil meal, 0.5% cod liver oil, and 2.0% complex mineral mixture. Rations fed lots 5 to 9 inclusive were calculated to contain 6.3 mcg. of vitamin B_{12} per pound. The rations fed each lot, the average daily gain, average daily feed consumed and the feed required per 100 pounds of gain were: (1) Basal; 1.44, 4.93, 342; (2) Basal plus riboflavin, ca-pantothenate and nicotinic acid; 1.72, 5.58, 339; (3) Basal plus 5% brewer's dried yeast; 1.49, 5.30, 355; (4) 2 with 50% of the protein supplied by tankage; 1.72, 5.84, 340; (5) 2 plus 0.05% APF supplement No. 1; 1.65, 5.58, 324; (6) 2 plus 0.05% APF supplement No. 2; 1.97, 6.06, 308; (7) 2 plus 0.25% APF supplement No .3; 1.72, 5.48, 318; (8) 2 plus 0.05% of APF supplement No. 4 which contained 30 gms. of streptomycin per pound; 1.82, 5.87, 322; (9) 2 plus 0.05% of APF supplement No. 5 which contained 15 gms. of penicillin per pound; 1.88, 6.00, 320.

THE EFFECTS OF ANTIBIOTICS FED AT LOW LEVELS ON THE GROWTH OF WEANLING PIGS. R. W. Luecke, H. W. Newland, W. N. McMillen and F. Thorp, Jr., *Michigan State College.*

Weanling pigs averaging 26 lbs. were group-fed various experimental rations for an 8 week period. Basal ration A was composed of corn, 72%; soybean oil meal, 25%; complex mineral mixture, 3%; and vitamins A and D. Ration B was composed of corn, 65%; soybean oil meal, 17%; meat and bone scraps, 5%; distillers dried solubles, 5%; dehydrated alfalfa, 5%; complex mineral mixture, 3%; and vitamins A and D. The term B vitamins used to describe additions to rations A and B indicate the addition of niacin, calcium pantothenate and

riboflavin in liberal amounts. The additions of streptomycin (S), aureomycin (A), and neomycin (N) were all made at levels of 10 mg/lb. of feed. Penicillin (P) addition was carried out at 1 mg/lb. of feed. The supplements fed and the average daily gains were as follows: Basal A (1) basal (0.57); (2) basal+S (0.71); (3) basal+B vitamins+S (1.15); basal+B vitamins+B_{12} (1.10); basal+B vitamins+B_{12}+S (1.17); basal+B vitamins+B_{12}+A (1.30); basal+B vitamins+B_{12}+P (1.30); basal+B vitamins +B_{12}+N (1.01). Mixed ration B, (1) basal (0.71); (2) basal+S (0.78); (3) basal+B vitamins+S (1.11). The addition of streptomycin and neomycin at levels of 10 mg/lb. of feed produced no additional growth response, but the additions of aureomycin or penicillin produced a significant growth response over the B vitamin supplemented basal ration.

A RELATIONSHIP BETWEEN TOTAL DIGESTIBLE NUTRIENTS (TDN) AND ESTIMATED NET ENERGY VALUES (ENE) AND A POSSIBLE METHOD FOR ESTIMATION OF NET ENERGY VALUES WITH PRODUCING DAIRY COWS.

L. A. Moore, *U. S. Department of Agriculture.*

When the values given by Morrison for all classes of feeds were plotted on semi-log paper with T.D.N. on the log scale and E.N.E. on the arithmetic scale, a straight-line function was evident. Therefore, a regression line was fitted to the data. From this linear relationship the changing energy value of T.D.N. is evident. Also if the linear relationship is true the E.N.E. value of feeds can be approximated from the T.D.N. value. In digestion trials, if one is interested only in the T.D.N. of feeds, this value can be calculated by the equation: T.D.N. =Dig. D.M.−Dig. Ash+Dig. Fat×1.25. Some preliminary data indicate that E.N.E. values of forages based on corn can be obtained with producing dairy cattle. After proper preparation, cows were fed a given quantity of corn and the forage to be tested for 10 days. The corn was then replaced for 10 days by an additional quantity of hay being tested in approximately isocaloric quantities. During the next 10-day period the same ration was fed as during the 1st 10-day period. The 4% F.C.M. for the last 5 days of each 10-day period was determined. The percentage difference in milk production for the middle 10-day period and the average of the other two 10-day periods was calculated and used in correcting the E.N.E. intake of the corn consumed. The corrected E.N.E. intake from the corn was then equated to the lbs. of hay which replaced the hay during the middle period.

SEASONAL VARIATIONS IN THE FEED AND WATER INTAKE IN CATTLE.

D. N. Mullick, V. N. Murty and N. D. Kehar, *Indian Veterinary Research Institute.*

There seems to be little information onthe metabolic behaviour of ruminants in the tropics affecting their general health and production. This investigation was designed to study the influence of seasonal rhythm on the metabolic behaviour of different nutrients in cattle. The digestibility trials and water metabolism were conducted on six adult kumauni hill steers (300–400 lbs.) in different seasons of the year. The average values of the air temperature and moisture were 67, 86, 98, 88, 64°F and 50, 42, 33, 81 and 69% in winter, spring, summer, autumn and winter respectively. The values of water intake and the insensible perspiration were 2.4 kg., 0.62 kg. and 4.0 kg., 2.0 kg. per 100 lb. body weight in winter and summer months. The urinary output and its specific gravity showed no change. The dry matter intake was 0.80 kg. and 0.73 kg. per 100 lb. body weight and the coefficients of digestion were 48 and 44 in winter and summer months respectively. The ratio between the dry matter and water intake showed that the water intake increased considerably in proportion with the changes in the dry matter with increased atmospheric temperature. Again, the same air temperature with higher moisture content decreased the water intake and the insensible perspiration. The intake of protein, fat and carbohydrate was 58 gm, 24 gm, 527 gm and 50 gm, 17 gm, 700 gm in winter and summer conditions. Protein with higher biological value and fat with higher caloregenic value helped in reducing heat production in animals by lowering the intake under unfavourable climatic conditions. The seasonal mean values of the intakes of all these nutrients including the dry matter and water were statistically significant.

ANTIBIOTICS, WHEY, AND APF FOR BABY PIGS. R. O. Nesheim, J. L. Krider, and B. C. Johnson, *University of Illinois.*

Two experiments were conducted with two-day-old baby pigs to study the effect of adding antibiotics, whey, and APF to nutritionally adequate "synthetic" milk rations. The pigs were individually fed equal feed intake in each experiment. 0.8 mcg. of vitamin B_{12} per kilogram of body weight per day was injected intramuscularly in each experiment. Two grams of sulfathaladine per liter of milk was added in the first experiment only. In the first experiment 16 pigs were allotted to 4 groups and fed a 30% alpha protein "synthetic" milk for 49 days. The treatments were as follows: lot 1, basal only; lot 2, 4% dried whey added replacing an isocaloric part of the basal diet; lot 3, 1% Lederle APF; lot 4, 500 mg. streptomycin/kg. dry matter consumed. The average daily gains for the 49 day period were 0.67, 0.64, 0.71, and 0.75 pounds respectively. The average daily gain and efficiency of feed utilization of the pigs receiving streptomycin was highly significant over the basal lot ($P<0.01$). In the second experiment a 30% vitamin-free casein "synthetic" milk was fed. Sixteen pigs were allotted to 4 treatments and received orally the following amounts of an antibiotic per kilogram of dry matter consumed: lot 1, basal only; lot 2, 100 mg. aureomycin; lot 3, 100 mg. penicillin; lot 4, 100 mg. streptomycin. The average daily gains for the 42 day experimental period were 0.78, 0.84, 0.84, 0.79 pounds respectively. None of the treatments gave a statistically significant increase in rate of gain or efficiency of feed utilization over the basal ration.

COMPARATIVE VALUE OF VITAMIN A AND CAROTENE FOR SUPPLYING THE VITAMIN A REQUIREMENTS OF SWINE DURING GESTATION AND BEGINNING LACTATION. D. B. Parrish, C. E. Aubel, J. D. Wheat and J. S. Hughes *Kansas Agricultural Experiment Station.*

In each of two trials, 15 Duroc gilts were divided into three comparable lots. Gilts in Lot I received a yellow corn-tankage ration plus high quality alfalfa hay *ad lib.* Gilts in Lots II and III received a low-carotenoid basal ration plus daily supplements of, respectively, either vitamin A or carotene at a level of 6500 units (one-half the N.R.C. allowances for vitamin A) in trial I and 7100 units in trial II. As judged by concentrations of vitamin A in blood serum and in colostrum of the gilts at farrowing time, and by concentrations of vitamin A in the blood serum and in the livers of new-born and of 5-day-old pigs, 6500–7100 units of vitamin A was almost as effective as the yellow-corn-tankage-alfalfa hay diet for supplying vitamin A during gestation and beginning lactation. Carotene appeared to have been approximately one-half as effective as vitamin A, except for liver storage. Livers of pigs whose dams received carotene contained only one-third to one-fifth as much vitamin A as did those from pigs whose dams received vitamin A. Size, health, and vigor of the pigs from sows of the three lots did not differ markedly. Vitamin A levels in the blood serum of the sows from each of the lots were lower at the time of farrowing than on the eighteenth, sixth or second days prepartum or on the second or fourth days postpartum.

RATION FACTORS AFFECTING EFFICIENCY OF UTILIZATION OF UREA NITROGEN. L. S. Pope, Willis D. Gallup, and C. K. Whitehair, *Oklahoma Agricultural Experiment Station.*

The value of urea as a nitrogen supplement in rations containing different proportions of roughage was investigated by nitrogen balance procedures with lambs. Three basal rations equal in protein content (6.5 percent, dry-matter basis) but containing 30, 50, and 85 percent of roughage as cottonseed hulls and a fourth ration containing 50 percent of roughage as prairie hay were supplemented with equal emounts of urea to raise the protein equivalent of the rations to 10 percent. The rations provided about 650 gm. of dry matter per day. Nitrogen balances for the basal and supplemented rations in order of increasing cotton seed hull content were +1.22 and +2.30 gm.; +0.26, and +0.55 gm.; and, −0.54 and −0.33 gm., respectively. Low nitrogen retention was associated with low digestibility of nitrogen in the basal ration. Efficiency of utilization of urea nitrogen at different levels of intake was studied in further

trials by adding increasing amounts of urea to a constant amount of a basal 40-percent cottonseed hull ration containing 7.0 percent of protein, dry-matter basis. The rations supplied from 625 to 635 gm. of dry matter daily. Daily nitrogen intakes on the basal and supplemented rations were about 7.0, 8.5, 10.2, and 12.5 gm.; nitrogen balances on these intakes were +0.56, +1.72, +2.44, and +2.30 gm., respectively. Urea improved crude fiber digestion. Replacement of urea and carbohydrates by equivalent amounts of cottonseed meal slightly increased nitrogen retention at the highest level of nitrogen intake but not at the lowest level. Methionine added at the rate of 1.6 gm. per day to the basal and urea-supplemented rations was of doubtful value at these levels of feed intake.

THE EFFECT OF ARTIFICIAL HEMORRHAGE VERSUS *HAEMONCHUS CONTORTUS* INFECTION ON CERTAIN BLOOD CONSTITUENTS OF LAMBS. R. M. Richard, T. L. Bahler, A. L. Pope, P. H. Phillips, C. A. Herrick, and G. Bohstedt, *University of Wisconsin.*

The stomach worm (*Haemonchus contortus*) proceduces a severe anemia in lambs. Previous workers have offered several postulations to explain the deleterious effect of this parasite. To obtain more conclusive evidence, 8 parasite-free lambs approximately three months of age were each infected with 40,000 stomach worm larvae and paired with lambs of similar weight and age. The non-infected lamb of each pair was bled daily to produce an anemia comparable to that of its infected mate. Four lambs served as controls. The lambs were maintained on four different rations throughout the experiment in order to study the effect of certain hematopoietic dietary factors on resistance to infection. Data were collected on fecal egg counts, hemoglobin levels, weight gains, blood riboflavin, plasma nicotinic acid and vitamin B_6. Additional lambs on each ration were sacrificed for post-mortem worm counts. Approximately four times the initial blood volume was removed from all but one of the non-infected lambs during the 45 day experimental period. Supplementation with a mineral mixture containi g iron, copper, cobalt, manganese, calcium, and phosphorus enabled lambs on both a high and low protein ration to better withstand stomach worm infection.

COBALT WITH A SOYBEAN OIL MEAL RATION FOR PIGS. W. L. Robison, *Ohio Agricultural Experiment Station.*

Pigs fed a mineral mixture containing 0.15 percent of cobaltous chloride with corn, dried distillers' grain solubles, soybean oil meal, and ground alfalfa made faster and more efficient gains than pigs without it or pigs without it but having meat scraps with soybean oil meal so each supplied equivalent amounts of protein. They gained 97.3 percent as rapidly and required 5.6 percent less feed per unit of gain than pigs having an APF concentrate presumably having no antibiotic effect. They required 98.9 percent as much feed per unit of gain but gained 10.1 percent less rapidly than pigs fed an APF concentrate from an aureomycin source and presumably having an antibiotic effect. The minerals were iodized salt, 19.2; limestone, 38.4; bone meal, 38.4; ferrous sulfate, 4. The cobaltous chloride replaced an equal amount of ferrous sulfate. The ration contained 0.00074 percent of cobalt. There were 13 pigs to the group. The pens were floored with concrete and were cleaned daily. In the first 12 weeks of a second trial the pigs with cobalt gained more rapidly than those without cobalt. They gained more slowly than those having cobalt and an aureomycin APF concentrate. They gained as rapidly but made less gain per unit of feed than pigs receiving cobalt and having meat scraps in place of the soybean oil meal.

VITAMIN B_{12} REQUIREMENT OF WEANLING PIGS FED A SEMI-SYNTHETIC RATION. D. Richardson, D. V. Catron, L. A. Underkofler and H. M. Maddock, *Iowa Agricultural Experiment Station.*

The purpose of this experiment was to determine the B_{12} requirement of the male pig from weaning to 75 lbs. Pigs farrowed by gilts which did not receive an added source of B_{12} during lactation were individually fed and watered in wire floor crates. Litter mates were used with 3 pigs per treatment. Lot I received a basal ration of 71% corn, 24.5% blended

solvent soybean oil meal, minerals, including trace minerals, and vitamins A, D_2, E, K, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, choline, folic acid, inositol, biotin, para-amino-benzoic acid and pyracin. Lots 2, 3 and 4 received the basal plus 5, 10 and 20 micrograms respectively of crystalline vitamin B_{12} per lb. of total ration. The average daily gain and feed per 100 lbs. gain were: lot 1, 1.19 lbs., 265; lot 2, 1.22 lbs., 236; lot 3, 1.25 lbs., 248; lot 4, 1.29 lbs., 233. Lots 5, 6, 7 and 8 received the same rations as lots 1, 2, 3 and 4 respectively plus 40 milligrams of antibiotics (10 each of aureomycin, streptomycin, terramycin and penicillin) per pound of total ration in an attempt to control bacterial synthesis in the intestine. The average daily gain and feed per 100 lbs. gain were: lot 5, 1.04 lbs., 235; lot 6, 1.54 lbs., 195; lot 7, 1.58 lbs., 192; lot 8, 1.53 lbs., 193. The effects of vitamin B_{12}, antibiotics and the vitamin B_{12}-antibiotic interaction were all significant at $P=.01$. Analysis of the blood showed no significant differences in hemoglobin, red and white blood cell counts and total nitrogen. Blood urea was significantly greater in lot 5. Vitamin B_{12} balance studies were made.

A.P.F. SUPPLEMENTS FOR CALVES. L. L. Rushoff, *Louisiana Agricultural Experiment Station.*

In June 1950 (1950 Annual Meeting American Dairy Science Association) we reported that supplements of Merck's A.P.F. no. 3 (0.5 mg. vitamin B_{12} per 100 lb. of feed) and injections of pure vitamin B_{12} (1 mg. per calf) were without effect on the growth of dairy calves weaned from whole milk at 28 days of age, and receiving an all-plant protein calf starter and alfalfa hay up to 13 weeks of age. The continued feeding of A.P.F. No. 3 to 5 calves up to 18 weeks of age was of no value. In this trial 5 Jersey male calves from the control group (14 weeks of age) were continued on a simple all-plant protein basal ration consisting of 1 part cottonseed meal, 3 parts yellow corn meal, 2% bonemeal and 1% salt; and 5 Jersey male calves from the A.P.F. group (14 weeks of age) were fed the basal ration containing 2% Lederle's A.P.F. containing aureomycin in place of A.P.F. No. 3. The animals were allowed pasture and some lespedeza hay. The A.P.F.-aureomycin group outgained the control group through the 6th week on experiment. The average daily gain per calf at this time (6th week) was 1.43 lb. for the A.P.F. group and 1.09 lb. for the control group. However, after 8 weeks on experiment the average daily gain for the A.P.F. group was 1.53 lb. and for the control group, 1.42 lb. The outstanding feature between the groups was the smooth hair, sleek solid muscular appearance of the A.P.F. calves, and the rougher appearance and larger middle of the control group.

EFFECT OF CALCIUM ON REPRODUCTION AND MILK PRODUCTION IN DAIRY COWS. L. L. Rushoff. *Louisiana Agricultural Experiment Station.*

This phase of nutritional studies with dairy animals was started in 1947. Four grade Jersey cows and 6 grade Jersey heifers were fed a limited amount (6 lbs.) of low quality (low Ca, low P) native grass hay along with a simple grain ration containing 3 parts of yellow corn meal, one part cottonseed meal, and 1% salt. This ration was fed at a 10% higher level than recommended by Morrison's standards. Shark liver oil supplied vitamin A since the animals had no access to pasture. They were bred by artificial insemination. It took 3 to 6 services for conception for all animals on this basal ration which terminated into 50% abortions for 1947 and 66% in 1948. All animals were free of Bang's disease. Heifers having first calves which did not abort, had calves born dead or very weak. This ration also produced some stiffness on walking, and in some cases, humped back, bent hind leg, swollen leg joints, depression at the base of the tail, and constant tongue licking. The blood picture for plasma Ca, plasma inorganic P, and hemoglobin was normal. In 1949 Ca (oyster shell flour) was supplemented daily to all animals. Only 1 to 2 services per conception were now required resulting in normal births. Slight improvement of symptoms occurred also. The administration of Ca also increased milk production as much as 50% in some cases, and maintained this high production until advanced lactation. This year Ca has been fed to milking animals every other month resulting in an increase in 4% F.C.M. yield for most animals when Ca was fed and a decrease in 4% F.C.M. when Ca was not given.

STUDIES ON THE DETERMINATION OF VITAMIN B_{12} IN MEATS. Harold E. Scheid and B. S. Schweigert, *American Meat Institute Foundation* and *University of Chicago.*

In previous studies (*J. Biol. Chem.* 185 1, 1950) assays for vitamin B_{12} were conducted with *L. leichmannii* 313 and 327 with 2 mg. cysteine in the medium. Considerable variation was noted in the response to vitamin B_{12} in some of the assays, consequently, a detailed study on variations in the basal medium, the addition of thioglycollic acid and other reducing agents, method of sterilization including aseptic additions of the samples, and the use of Seitz filtered preparations was conducted. The addition of thioglycollate to the medium and sterilization by autoclaving for 10 minutes resulted in essentially the same response to vitamin B_{12} (as crystalline vitamin B_{12}, vitamin B_{12b}, liver extracts or digests of fresh liver) as was obtained with aseptic additions of the samples or with the samples and medium sterilized by Seitz filtration. A number of enzyme preparations (pancreatin, trypsin, erepsin, takadiastase, and bacterial preparations) has been investigated for the liberation of vitamin B_{12} in meats. The vitamin B_{12} activity of meats measured with *L. leichmannii* was increased 2 to 3-fold by enzymatic treatment as compared to the results on cold water extracts. Samples of liver extracts, beef liver and round have also been assayed by the rat and chick assay. The limited data obtained indicate that the vitamin B_{12} potency of these products determined with different assay organisms is essentially the same.

PROXIMATE COMPOSITION, T.D.N., AND DIGESTIBLE ENERGY OF FEEDS. Burch H. Schneider and Helen M. Pavlech, *State College of Washington* and *West Virginia University.*

In the symposium at the 1949 meetings of the *Society*, some questions were raised regarding *Digestible Energy*. To contribute to their answer, the authors selected 497 digestion trials in which the heat of combustion was determined on both feed and feces and the digestion coefficient of the calories calculated. These trials were conducted by 121 authors on 72 feeds. Sheep and cattle data were kept separate. Feeds were divided into classes as hays, silages, concentrates, etc. Also, digestibility of feeds fed alone and "by difference" were handled separately. With cattle, the T.D.N. means for hays, silages, and concentrates on a moisture-free basis were 56.8, 64.9, and 73.2, respectively. The digestible calories per gram were 2.49, 2.61, and 3.64, respectively. The correlation coefficients between digestible energy and T.D.N. computed on trials within feeds varied from 0.91 to 0.96. The ratio, T.D.N. digestible calories per gram, varied from 20.1 to 24.9. It is possible to predict digestible energy by a regression equation of the same type previously reported to predict other digestibility values. It was not observed that digestible energy provides a measure that is superior to T.D.N. in practice. Its chief advantage appears to be theoretical in that energy units, calories, are used to measure energy. Physiologically, the digestible energy values used in these studies ignore the energy losses of the combustible gasses as does T.D.N.

COMPARISON OF GROWTH RESPONSES TO STREPTOMYCIN, AUREOMYCIN AND CRUDE AFP, ALONE AND IN COMBINATION WITH B_{12} ON 2-DAY-OLD PIGS USING A "SYNTHETIC" MILK. B. E. Shefchik, Carlos Acevedo, R. H. Grummer, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Eight lots of 4 pigs each were fed a B_{12} deficient "synthetic" milk, to determine the growth response of 2-day-old pigs to various antibiotics. The pigs were fed for 26 days as follows: Lot I, Basal; Lot II, Basal+B_{12}; Lot III, Basal+streptomycin; Lot IV, Basal+aureomycin; Lot V, Basal+B_{12}+streptomycin; Lot VI, Basal plus B_{12}+aureomycin; Lot VII, Basal+B_{12}+streptomycin+aureomycin; Lot VIII, Basal+Lederle's crude APF. Results indicate that aureomycin gave a greater growth response than did streptomycin. A combination of the two antibiotics gave the best results. Lederle's crude APF fed at a level of 1 gram per kilo of milk did not produce gains as favorable as B_{12} alone. Hemoglobin data did not show any consistent differences betweeen lots.

CHANGES IN VARIOUS CONSTITUENTS OF SOWS' MILK FROM COLOSTRUM TO 30-DAY MILK. B. E. Shefchik, H. A. Dymsza, R. H. Grummer, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

A study was made of the following constituents in colostrum, 15- and 30-day milk of 20 experimental sows, in an effort to note the influence of stage of lactation: total protein, casein protein, fat and fat phospholipid. Further, the following fat constants were determined: saponification number, Hehner number, percent soluble fatty acids, and the iodine number. The protein data indicate a high total protein level the first day with the average 15- and 30-day levels, being about the same. The casein protein, however, remains uniform throughout. The fat values show a definite decrease from 1st day to 15th day and to 30th day milk. The phospholipid levels when expressed as percentage of the fat, increase from the 1st to 30th day of lactation. The iodine number was consistently higher in colostrum than in 15-day and 30-day milk, but the other fat constants did not vary with stage of lactation. The fat constants indicate that the milk fat of swine is very similar to the body depot fats or lard.

FURTHER STUDIES ON THE AMINO ACID REQUIREMENTS OF SWINE. D. C. Shelton, W. M. Beeson and E. T. Mertz, *Purdue Agricultural Experiment Station.*

Purified diets have been prepared to study (1) the quantitative lysine requirement and (2) the quantitative methionine and cystine requirement of weanling pigs. In each experiment, the ration contained dextrose, dextrin, minerals, lard, celluflour, liver extract, vitamins and a source of protein which was low in the amino acid under investigation. For the lysine experiment, 16.0% zein, 10.0% gelatin, 0.3% tryptophan, 0.5% methionine and 0.2% histidine were used as the source of protein. L-lysine · HCl was added so as to have five different rations containing 0.5, 0.8, 1.0, 1.2 and 1.4% L-lysine, respectively. Each level of lysine was fed to two Duroc pigs. Increased growth rates were observed up to 1.0% L-lysine, but higher levels of L-lysine did not induce higher rates of gain or feed efficiency during the 35-day experimental period. For the methionine experiment, 12.0% oxidized casein, 10.0% gelatin and 0.3% tryptophan were used as the source of protein. Five rations were prepared to contain 0.1, 0.1, 0.6, 0.3 and 0.6% methionine and 0.01, 0.61, 0.01, 0.31 and 0.61% cystine, respectively. Each ration was fed to two Duroc pigs for 28 days. Average daily gains of 0.1, 0.35, 1.27, 1.28 and 1.32 lbs., respectively, indicate that 0.6% methionine, or 0.3% methionine plus 0.3% cystine is adequate to meet the requirement of the weanling pig for the sulfur-containing amino acids.

EFFECT OF THE ADDITION OF SALT VS. NO SALT UPON DIGESTIBILITY OF CERTAIN RATIONS, GROWTH, AND CONDITIONS OF STEERS. Ed. F. Smith, D. B. Parrish, and A. J. Clawson, *Kansas State College.*

In three different trials, using a total of 22 animals, the digestibility of rations by steer calves that for four to five months have received salt only as it naturally occurred in the feeds, was compared with that by steers that had received the same rations plus 18 to 28 gm. of salt daily. In each of the trials the average apparent coefficients of digestibility of dry matter, crude protein, ether extract, crude fiber, and nitrogen free extract, were from 0 to 4 (av. 1.6) percent greater by steers receiving salt than by those not receiving salt. The average apparent coefficients of digestibility of ash by steers in the three trials were, respectively, 5, 7, and 3 percent greater by those receiving salt. Steer calves wintered on dry bluestem grass plus one and one-half pounds of soybean pellets per head daily, gained an average of 60 pounds in 134 days, while those without access to salt gained 15 pounds. During the summer period of 58 days on grass the gains were respectively 152 pounds and 116 pounds. On full-feed in the dry lot for 135 days, the respective gains were 349 pounds and 355 pounds.

TRACE MINERALS FOR GROWING-FATTENING SWINE FED IN DRYLOT. V. C. Speer, D. V. Catron, P. G. Homeyer, C. C. Culbertson, *Iowa Agricultural Experiment Station.*

Four replicated lots of six pigs each were self-fed from weaning to 200 pounds. The lots

were orthogonal with respect to litter and levels of trace minerals fed to dams and litters during gestation and lactation. The basal ration was composed of yellow corn, soybean oil meal, meat and bone scraps, dehydrated alfalfa meal and a simple mineral mixture, and vitamins A, D_2, E, seven B-complex vitamins and APF supplement. The mineral mixture was composed of ground iodized limestone, steamed bone meal and salt. Iron, copper, manganese, cobalt, potassium and zinc were added to the basal ration at 1x, 2x, and 3x levels. Hemoglobin readings were taken at the beginning and end of the experiment. The adjusted mean daily gains (pounds) for 0x, 1, 2x, and 3x, levels of trace minerals were 1.73, 1.76, 1.81, and 1.74 respectively. Mean daily gains (pounds) of the pigs according to previous treatments 0x, 1x, and 2x levels of trace minerals were 1.70, 1.73, and 1.82. The average daily gains were significantly influenced ($P=0.05$) by the level of trace minerals fed during the growing-fattening period as measured by the regression of average daily gain on the level of trace minerals. The regression fitted was a second degree parabola, $Y=a+bX+cX^2$. The difference in average daily gains due to previous treatment (comparing 0x, and 2x levels of trace minerals) was statistically significant at $P<0.01$ in favor of the addition of trace minerals. There were no significant differences in feed efficiency or in hemoglobin readings.

THE USE OF DETOXIFIED COTTONSEED MEAL IN SWINE NUTRITION
Edward L. Stephenson and A. L. Neumann, *University of Arkansas.*

This study was made to compare the toxic principles of three differently processed cottonseed meals when used in rations for growing pigs. The cottonseed meals were fed in quantities calculated to be sufficient to supply the total amount of protein necessary to supplement an all-vegetable diet for swine. An additional six percent of fish meal was added to compensate for an animal protein factor or amino acid deficiency. Of the three meals tested only one appeared to be non-toxic at the levels fed. This meal, an experimental product secured through the courtesy of the Southern Regional Research Laboratory, supported excellent growth and none of the pigs receiving this meal showed any toxic symptoms. The pigs receiving the other two meals died approximately six weeks after being placed on the experiment.

A COMPARISON OF THE COPPER VALUES IN THE BLOOD SERUM OF SWINE WITH THAT OF OTHER FARM ANIMALS. H. A. Stewart, Gennard Matrone, J. A. Weybrew and Hartlee M. Baxley, *North Carolina State College.*

Determinations of copper values of the blood serum of cattle, sheep, and swine at the North Carolina Experiment Station have shown these values for swine to be twofold greater than those of the other species. Values found for both cattle and sheep were about 100 μg./100 ml. of blood serum. These values were obtained from animals representing four breeds of cattle and purebred Hampshire sheep. The mean value found in 122 determinations made on the blood of swine from 3 months to 1½ years of age was 238 μg./100 ml. of serum. The copper content of the blood serum of new born pigs was found to be extremely low by comparison. Fourteen pigs from 2 litters had a mean value of 31 μg./100 ml. The copper content of the total livers of these pigs indicates that pigs could be expected to have blood serum copper values comparable to older swine. The relationship between the total copper in the liver and the serum copper in the blood may be independent of one another, or may be inversely related. The variation between pigs in serum copper of the blood is great; however a significant difference was found between litters.

THE EFFECT OF ALFALFA ASH UPON ROUGHAGE DIGESTION IN SHEEP. R. W. Swift, R. L. Cowan, and G. P. Barron, *The Pennsylvania State College.*

The apparent digestibility of a ration in which the chief source of crude fiber was ground corn cobs was determined with and without alfalfa ash in a series of 41 11-day collection periods with sheep. In 8 calorimeter periods using 4 sheep in each period there was also determined the production of methane, carbon dioxide, heat and metabolizable energy. The digestibility of crude fiber was increased by the addition of alfalfa ash from 43% to 53% (highly significant) with smaller increases in digestibility of dry matter, protein and nitrogen-

free extract. The increase in digestible energy was small (61.0% to 62.5%) but this slight increase agrees quantitatively with the increase of 10% found in crude fiber digestion. Alfalfa ash increased the production of methane by about ten percent and the metabolizable energy of the ration was increased by 1.5 percent.

A COMPARISON OF SOLVENT SOYBEAN OIL MEALS AND THE EFFECT OF ADDING AUREOMYCIN, DRIED WHEY PRODUCT WITH WHEY FERMENTATION SOLUBLES, AND APF IN DRYLOT RATIONS OF WEANLING PIGS. S. W. Terrill and J. L. Krider, *University of Illinois.*

Six lots of 10 pigs each were self-fed a 20% crude protein corn-soybean oil meal ration in drylot (concrete) from weaning to 75 pounds in live weight. The treatment and average daily gains for lots 1–6 were as follows: (1) 64.2% ground yellow corn, 32.5% regular solvent soybean oil meal, 1% steamed bone meal, 2% mineral mixture, 0.2% dry vitamin A and D mix, and fortified with riboflavin, calcium pantothenate, niacin, choline chloride and 0.1% vitamin B_{12} concentrate (1.13); (2) same as 1 except that a special solvent soybean oil meal processed for 45 minutes in the presence of live steam (212°F) at atmospheric pressure was used (1.14); (3) a high protein solvent soybean oil meal without hulls was used (1.12); (4) same as 3 plus 5% dried whey product with whey fermentation solubles (1.06); (5) same as 3 plus 5% dried whey product with whey fermentation solubles and APF concentrate (1.22); (6) same as 3 plus 25 mg. of aureomycin hydrochloride per pound of ration (1.43). The 0.1% vitamin B_{12} concentrate was omitted from the rations of lots 4 and 5. Performance of the pigs in lots 1, 2 and 3 indicate that the soybean oil meals used were equally effective in promoting growth. Pigs in lot 5 made 15% faster gains than pigs in lot 4, but the difference was not statistically significant. The addition of aureomycin hydrochloride to the ration (lot 6 versus lot 3) resulted in 28% faster gains (highly significant).

DIETARY RELATIONSHIP BETWEEN VITAMIN B_{12} AND QUANTITY OF PROTEIN. Byron H. Thomas and Edmund Wei Cheng, *Iowa State College.*

The beneficial effects of feeding concentrates of the animal protein factor (APF) to pigs, chicks and laboratory animals have been demonstrated again and again. The identity of APF still is unknown. A markedly effective component of APF is vitamin B_{12}. Many workers reported B_{12} to have growth-stimulating properties similar to that of concentrates of APF. To our knowledge no one has determined whether an optimum relationship exists between levels of dietary protein and vitamin B_{12}. Data bearing on this point have been collected. Since large numbers of animals were required, rats were used in the interest of economy. Ninety-six weanling rats were randomized into 16 groups of 6 rats each. The rats were caged individually and received semi-synthetic rations containing either 8, 12, 18, or 36 percent "vitamin-test" casein, and intraperitoneal injections of either none, 0.025, 0.050, or 0.100 micrograms daily of crystalline B_{12}. The rats which received B_{12} grew markedly faster than those which received no B_{12}. Also, they required less ration to produce equal gains in live weight. Furthermore, they grew as well or faster than rats which received rations containing larger percentages of protein unsupplemented with B_{12}. Analyses of these data indicate, up to a certain point, that the efficiency of these rations is correlated with level of protein and quantity of injected vitamin B_{12}. Whereas, the optimum efficiency relationship for these nutrients was not determined specifically, the data indicate this to be a combination of about 18 percent casein and 0.05 micrograms of vitamin B_{12}.

SUPPLEMENTING A CORN SOYBEAN OIL MEAL RATION WITH AN APF CONCENTRATE, DRIED WHEY WITH WHEY FERMENTATION SOLUBLES, AND A COMBINATION OF COMMONLY USED FEED SUPPLEMENTS FOR BROOD SOWS IN DRYLOT. R. F. Van Poucke, O. D. Hanson, H. T. Peeler and N. E. Rodgers, *Western Condensing Company.*

Five groups of sows with similar nutritional histories were fed in drylot from breeding

through weaning. The 17% crude protein basal diet contained 72.9% corn, 24.0% soybean oil meal, 1.5% steamed bonemeal, 0.5% iodized salt, 1.0% limestone, 0.01% manganese sulfate, 0.02% ferrous sulfate, 0.002% copper sulfate, 0.125% A and D supplement and 0.7 mg riboflavin per lb. of feed. Supplements, percentages of pigs weaned, average weaning weights (56 days) and average litter weights at weaning were as follows: (1) none (6.9%) (18.5 lbs.) (9.3 lbs.); (2) 0.1% Merck's APF supplement No. 3 (65.4%) (25.7 lbs.) (146.2 lbs.); (3) 5.0% dried whey-product with whey fermentation solubles (70.6%) (29.8 lbs.) (178.5 lbs.); (4) same as (3) plus 0.1% Merck's APF supplement No. 3 (82.4%) (30.0 lbs.) (210.0 lbs.; (5) same as (3) plus 2% fish solubles, 5% alfalfa meal and 4% meat scrap (88.4%) (29.4 lbs.) (223.4 lbs.). Very poor lactation results were obtained with sows fed the basal diet. Vitamin B_{12} improved percentage of pigs weaned and average weaning weights. Supplementation with dried whey-product with whey fermentation solubles resulted in greater percentage of pigs weaned and higher weaning weights than was promoted by vitamin B_{12}. A combination of these two supplements promoted no greater weaning weight per pig than dried whey-product with whey fermentation solubles alone, but the larger percentage of pigs weaned made possible a larger average litter weight than either of the preceding two treatments. The lot 4 response approximated that of the positive control group.

APF SUPPLEMENTS FOR GROWING PIGS. A. B. Watts, M. P. Botkin, J. A. Whatley, and O. B. Ross, *Oklahoma A. & M. College.*

The objective of this study was to determine the practicability of replacing the animal protein in supplemental mixtures for growing and fattening pigs. All lots were self-fed shelled corn, free choice, and four supplemental mixtures, self-fed, free choice, were tested. Four replicated lots of four linecross weanling Duroc pigs weighing 28 to 36 pounds initially were fed each ration. The percentage composition of the supplemental mixtures fed the various lots were: Lot 1—fish meal 19.2, tankage 19.2, cottonseed meal 19.2, soybean meal 19.2, alfalfa meal 19.2, trace mineralized salt 2.0, and bone meal 2.0; Lot 2—tankage 19.2, cottonseed meal 19.2, soybean meal 32.4, alfalfa meal 19.2, trace mineralized salt 3.0, bone meal 3.0, and an APF supplement containing aureomycin 4.0; Lot 3—cottonseed meal 32.9, soybean meal 33.9, alfalfa meal 19.2, trace mineralized salt 3.0, bone meal 6.0, calcium carbonate 1.0, and an APF-supplement containing aureomycin 4.0; and Lot 4—tankage 19.2, cottonseed meal 19.2, soybean meal 34.4, alfalfa meal 19.2, trace mineralized salt 3.0, bone meal 3.0, and an APF supplement containing 12.5 mg. of vitamin B_{12} per pound. For an 84-day feeding trial the average daily gain and feed consumed per 100 pounds of gain for the four replicated lots fed the supplements were: Lot 1, 1.52 and 331; Lot 2, 1.70 and 318; Lot 3, 1.73 and 314; and Lot 4 1.56 and 321. There were significant differences among the lots as to rate of gain but differences in feed consumed per 100 pounds gain were not significant.

HIGHLY PURIFIED RATIONS FOR SHEEP. William C. Weir, *University of California.*

Two-day-old lambs have been reared to eight weeks on purified diets. "Synthetic" milk I was prepared by dissolving casein in sodium bicarbonate, adding dextrose, homogenizing in the lard and then adding all of the mineral mixture at one time. Synthetic milk II was prepared by dissolving casein in calcium hydroxide, adding other salts in a series of solutions, adding dextrose, and finally emulsifying lard with lecithin. Both milks were supplemented with vitamins A, D, E and B complex. All of the lambs fed these milks grew much slower than their twins which remained on the ewe. A purified dry feed composed of starch, dextrose, lard, casein, minerals, cellulose acetate and vitamins A and D, has been compared to oat hay as a supplement to the "synthetic" milk. The lambs consumed less dry feed and their growth was slower, especially in the latter part of the period, than the lambs receiving oat hay. Substituting butter oil for the lard in synthetic milk II did not improve the growth of the lambs.

THE EFFECT OF LEVEL OF NUTRITION ON REPRODUCTION AND LACTATION IN SHEEP. C. K. Whitehair, R. L. Nash, and W. D. Gallup, *Oklahoma A. & M. College.*

An experiment was conducted to determine what nutrients were needed to supplement a basal ration of native hay from eastern Oklahoma in order to obtain normal reproduction and lactation in sheep. Special emphasis was given to the value of increasing the protein and energy content of the hay ration. Thirty head of four and five year old ewes were equally divided into 5 lots, bred, and started on experiment November 1, 1949. Lot 1 was fed the basal ration of native hay. Lot 2 was fed the basal hay ration plus corn starch. Lot 3 received the hay ration with the addition of corn and corn gluten meal. Lot 4 was fed the same ration as lot 3 plus dicalcium phosphate. Lot 5 was fed the same ration as lot 4 with the addition of the trace minerals and codliver oil. The gain or loss in body weight during pregnancy appeared to be in relation to the type and quantity of nutrients fed. The ewes in lot 1 and lot 2 suffered heavy losses of body weight during pregnancy. At lambing time they were emaciated, weak, lacked maternal instinct, and had very poor udder development. Eighty-two percent of the lambs in lot 1 and seventy-five percent of the lambs in lot 2 were either dead at birth or died shortly thereafter. The ewes in lots 3, 4, and 5 maintained their body weight during pregnancy and lactation. They gave birth to lambs that were normal in size, vitality, and growth. The hemoglobin, hematocrit, and plasma protein values were lower for lots 1 and 2 than for the other three lots. The phosphorus, calcium, and vitamin A blood values were about equal for all lots.

UREA, N.P.N., AND BLOOD SUGAR VALUES OF BABY PIGS EXPOSED TO TRANSMISSIBLE GASTROENTERITIS. C. K. Whitechair, A. B. Watts, and O. B. Ross, *Oklahoma A. and M. College.*

These studies were conducted to try to determine the causes of high urea and nonprotein nitrogen (N.P.N.) blood values that were associated with naturally occurring baby pig losses. In preliminary studies the increase in urea and N.P.N. blood levels could not be associated with the type of ration fed—such as an all plant ration. Healthy baby pigs were allowed to nurse the sow and were exposed to material known to cause gastroenteritis in baby pigs. Exposure of two litters of 1-day-old pigs caused an average increase of blood urea from 23 to 215 mg. per 100 cc. on the 7th day. Exposure of two litters of 5-day-old pigs caused an average increase of blood urea from 6.7 to 41 mg. per 100 cc. by the 7th day. Exposure of two litters of 21-day-old pigs caused an average increase from 12.8 to 23.1 mg. per 100 cc. on the 7th day. All pigs dying from exposure to the infectious agent had high urea and N.P.N. values shortly before death. Clinical recovery from this infectious agent was associated with a return of urea and N.P.N. to normal values. A decrease in blood sugar values from the time of exposure until the 7th day was also observed.

PROTEIN REQUIREMENTS OF MATURE RANGE EWES FOR LAMB AND WOOL PRODUCTION. Frank Whiting and Sydney B. Slen, *Dominion Experimental Station.*

Experiments were carried out, using 3 groups of 27 mature range ewes, individually fed in drylot for a period of one year (June, 1949 to June, 1950) to study the effect of level of protein in the ration upon lamb and wool production. The levels of total protein fed were 7% (group 1), 10% (group 2), and 13% (group 3). The 3 rations, fed in pelleted form, contained 70% roughage (grass hay) and 30% concentrate, and contained the same percentage of T.D.N. and minerals. Total feed intake was approximately the same for all groups. Each ewe carried one lamb when placed on experiment. The lambs were weaned in Sept. and the ewes were bred to lamb during April, 1950. The av. birth wts. were 9.4, 11.4, and 10.6 lbs. for single lambs and 7.6, 8.6, and 8.8 lbs. for twin lambs for groups 1, 2, and 3 resp. The av. wts. of all lambs alive on June 12 with the lambing percentages, (based on lambs alive on June 12 and ewes that lambed), shown in parentheses were 34.6 (56%), 42.2 (89%), and 42.0 lbs. (108%) for groups 1, 2, and 3 resp. The av. clean fleece wts, were 4.8, 5.6,

and 5.7 lbs. for groups 1, 2, and 3 resp. In all cases the differences between groups 1 and 2 were statistically significant but the differences between groups 2 and 3 were not significant. On the basis of one year's results it is concluded that 7% total protein in the ration of mature ewes is insufficient for optimum lamb and wool production but there is little advantage in feeding more than 10% protein if the ewes receive adequate energy.

DRIED BLOOD SUPPLEMENTS IN SWINE-TYPE RATIONS. O. H. M. Wilder, C. R. Myers, M. W. Darrow and Maude M. Hanke, *American Meat Institute Foundation.*

Several levels of dried blood were fed in a swine-type ration to laboratory rats to determine the optimum level for use in ordinary swine rations. A basal ration was used containing corn, alfalfa meal, minerals, and vitamins. Protein supplements were meat and bone scrap, or a mixture of meat and bone scrap and soybean oil meal, and dried blood additions were made to replace an equivalent amount of protein. A commercial APF product was also used in some rations. The greatest gain in weight was obtained when meat and bone scrap and APF were fed. Using this as a standard, other supplements gave the following comparative gains: meat and bone scrap alone, 80%; meat and bone scrap and 2% dried blood, 94%. Higher levels of dried blood gave progressively less growth unless APF was also included, in which case 4 and 6% dried blood gave 97% weight gains. The meat and bone scrap and soybean oil meal in a 1:1 protein ratio gave 93% gain, which was lowered when dried blood was added. When APF was included in the meat and bone scrap-soybean oil meal combination, up to 6% dried blood did not retard growth. Using this APF product, soybean oil meal alone gave 90% weight gains, and without APF 74%. It is concluded that dried blood can be used to advantage at a 2% level in a ration, or if APF is included, up to 6% dried blood may be used.

EFFECT OF CERTAIN MILK PRODUCTS RECONSTITUTED WITH DIFFERENT TYPES AND AMOUNTS OF FAT UPON GROWTH AND CERTAIN BLOOD CONSTITUENTS OF YOUNG DAIRY CALVES. J. M. Wing, R. S. Allen and N. L. Jacobson, *Iowa State College.*

Thirty-five Holstein calves, after being allowed to remain with their respective dams for three days following birth, were divided into seven comparable groups of five animals each. One group received whole milk containing 3% fat. The other six groups were fed, over a 56-day period, reconstituted milks containing various combinations of dried skim-milk, dried whey product, hydrogenated soybean oil, butter oil and water. Four of the experimental rations contained 3% fat whereas two contained no added fat. Since the experimental rations were compounded to be calorically equivalent to the whole milk control diet, the low-fat diets contained approximately 18% solids. Each calf received daily per 100 lbs. body weight 10 lbs. of its respective milk and 12,000 I.U. of vitamin A. No other feeds were offered. Recorded observations of the responses of the calves to the various diets included health, weight changes, blood hemoglobin and glucose levels, and blood plasma inorganic phosphate-calcium, fat, vitamin A and carotenoid values. The calves fed the control ration gained some, what more weight and exhibited a lower incidence of diarrhea than those receiving the other diets. Inclusion of fat in the rations did not enhance plasma vitamin A levels or growth, but resulted in less scouring. Rations containing butter oil resulted in higher blood plasma carotenoid and fat levels than those including hydrogenated soybean oil. No significant differences in the other blood constituents were observed among the various groups.

Pasture and Range Section

R. M. Forbes, *Chairman*

PROTEIN AND VITAMIN SUPPLEMENTS FOR GROWING-FATTENING PIGS ON LADINO CLOVER AND ON ALFALFA. C. E. Barnhart, *University of Kentucky.*

Comparison was made of (1) meat scraps, (2) dried corn distillers' solubles, and (3)

animal protein factor, when fed with soybean oil meal and ground yellow corn to growing-fattening pigs on ladino clover and on alfalfa pasture. The meat scraps and dried corn distillers' solubles were fed at the rate of 6 percent of the total ration, and the animal protein factor was added at the rate of 0.25 percent of the total ration. Crude protein of the three rations was maintained at a constant level, and was adjusted in accordance to the weight of the pigs. A simple mineral mixture of limestone, steamed bonemeal, and salt was self-fed. Seven pigs with an average initial weight of approximately 60 pounds were placed in each lot and self-fed the experimental rations for 74 days. Average daily gain for the pigs grazing ladino clover was as follows: ration 1, 1.87 lbs.; ration 2, 1.84 lbs.; and ration 3, 1.89 lbs. Average daily gain for the pigs grazing alfalfa was as follows: ration 1, 1.86 lbs.; ration 2, 1.91 lbs.; and ration 3, 1.94 lbs. Pigs grazing the ladino clover consumed 331.75, 325.49, and 320.37 pounds of feed for 100 pounds of gain on rations 1, 2, and 3, respectively. Pigs grazing alfalfa consumed 321.53, 320.04, and 311.61 pounds of feed for 100 pounds of gain on rations 1, 2, and 3, respectively.

MAXIMUM UTILIZATION OF ROUGHAGE AND PASTURE IN THE PRODUCTION OF FAT LAMBS. Albert J. Dyer, *University of Missouri.*

Two groups of range ("Northwestern") ewes, five years of age, bred to a Hampshire ram for April lambs were used in this test wherein maximum utilization was made of roughage and pasture in the production of fat "late" lambs. Bluegrass pasture was the only roughage provided both groups during pregnancy except when inclement weather prevented grazing. During the last six weeks of the gestation period, one group was fed a grain mixture but neither group received grain during lactation. All ewes and lambs grazed together on various pastures. In early July, one half of each group of lambs was shorn to study the effect thereof on lamb gains. Lambs were weaned August 15, grazed until late November, and were fed grain thereafter in dry lot until they would grade "choice" or until January 7. Some of the more important observations made in the test are as follows: (1) feeding a grain mixture during late pregnancy resulted in heavier lambs at birth but no difference in performance after that; (2) all lambs were weaned within a short period of 22 days; (3) shorn lambs gained only slightly faster than full fleeced lambs; (4) 85% of the total gain required to finish was made from pasture; (5) only .9 bushel grain properly supplemented was required to finish the lambs at an average weight of 104 pounds; (6) planned late lamb production may fit well into farming operations over a wide area.

PRODUCING FAT YEARLING STEERS UTILIZING MAXIMUM AMOUNTS OF ROUGHAGE AND PASTURE. A. J. Dyer and Paul Guyer, *University of Missouri.*

The feeding test encompassed three phases—(1) wintering (2) grazing and (3) full feeding in dry lot. In the wintering phase, three types of rations were compared e.g., those containing roughage only, roughage supplemented with protein concentrate and roughage plus a grain mixture. These rations were compared as such and also as to the way they influenced the rate of gain made subsequently on wheat-lespedeza pasture during the second phase of the test. Fertilized pastures produced more total gain than unfertilized, but the daily rate of gain was the same. At the end of the grazing season, all cattle were full fed the same ration in dry lot until they would grade "good." From 60 to 65 percent of the total gain required was made from roughage and pasture combined. From 33 to 42 percent of the total gain was made from the latter. The rate of gain on pasture was in reverse order to the rate of gain in winter except for one lot of cattle. Because all lots of cattle weighed nearly the same at the end of the grazing season and required about the same amount of grain to fatten to the same grade, the simplest winter ration (roughage only) proved to be the most satisfactory one in this system of producing fat yearlings. About 26.5 bushels of corn were required to fatten these cattle to an average weight of 1103 pounds. This test reveals the wide use that cattle can make of roughage and pasture in producing "good" beef.

EFFECTS OF PHOSPHATE FERTILIZATION ON THE NUTRITIVE VALUE OF THE SOYBEAN PLANT. Gennard Matrone, F. H. Smith, J. A. Weybrew, V. B. Weldon, W. J. Peterson and W. W. Woodhouse, *U. S. Plant, Soil and Nutrition Laboratory, and North Carolina Agricultural Experiment Station.*

During the first two years of work, no clear-cut evidence was obtained that phosphate fertilization influenced either the chemical composition or the nutritive value of soybean plants. In the third year (1947 crop) the phosphate-fertilized forage had a significantly higher concentration of crude protein, phosphorus, calcium and magnesium and lower N-free extract than did the non-phosphated forage. In the 1948 crop the protein was higher in the non-phosphated hay but the phosphorus was higher in the phosphated hays. These differences were manifested not only in the plant as a whole but also in the leaves and the stems. In the 1947 hay crop, phosphate-fertilized soybeans had a higher nutritive value for lambs and rabbits than did the non-phosphated hay. This difference in the case of the sheep appears to be due to the extra phosphorus in the fertilized hay. Inasmuch as the protein and the phosphorus factors were eliminated in the rabbit studies, the factors responsible for the nutritional difference were not discovered. No evidence of differences in the availability of either the phosphorus or the protein of the soybean hay fed to rabbits and to lambs was detected.

COMPARISON OF THE DIGESTIBILITY OF CERTAIN PASTURE FORAGES IN THE FRESH AND THE DRIED STATES. W. J. Miller, G. Matrone and R. K. Waugh, *North Carolina Agricultural Experiment Station.*

Forage can be handled more conveniently in the dried state than in the fresh for digestion studies. Rabbits were used in a series of 24 digestion trials to determine whether or not drying affected the digestibility of three species of pasture herbage. The comparative digestibilities of fresh and of dried (60°C). immature Ladino clover, tall fescue (alta), and orchard grass were determined. Artificial drying of these three forages did not affect the total digestible nutrients. Drying did, however, increase the digestibility of the crude fiber ($P = .05$) in both of the grasses while decreasing the digestibility of the protein ($P = .01$) and the lignin ($P = .05$) of all three of the forages. Tall fescue (T.D.N. = 47.7) and orchard grass (T.D.N. = 49.8) were of about the same digestibility but Ladino clover (T.D.N. = 76.5) was more digestible than either of the grasses. There was a significant apparent digestibility of lignin by the rabbits on the Ladino clover. Moreover, the lignin in the green forage was slightly but significantly more digestible than the lignin in the dry forage. The lignin of the dried grasses was not digested appreciably by the rabbits.

THE EFFECT OF ADVANCE IN PASTURE SEASON ON MILK PRODUCTION. V. M. Patil, J. W. Wilbur, and N. S. Lundquist, *Purdue University,*

The results of eleven years of grazing trials with dairy cows have been reviewed. The pastures involved included alfalfa-grass mixtures, blue grass, sudan grass and alto fescue. Based on percentage of initial F.C.M. production, it was found that production decreased at a rather uniform rate with advance in grazing period. Standard deviations of items for week means are smaller at the beginning and became larger as the season advanced. The regression of percent initial F.C.M. production, with advance in season, on initial level is highly significant. The correlation coefficient was -0.336 and the regression coefficient -0.745. The correlation coefficient of initial level of F.C.M. with F.C.M. produced per day is 0.560 (regression 0.383) and is highly significant. On the basis of these observations, a proposed curve of milk production for the pasture season has been developed for cows of low, medium and high production.

THE EFFECT UPON MILK PRODUCTION OF ALFALFA HAY WHEN FED ALONE AND WITH CONCENTRATES. J. C. Shaw, H. M. Irvin, P. Saarinen, M. A. Sami, G. M. Cairns, and L. A. Moore, *University of Maryland* and *U.S.D.A.*

Eleven different hays obtained from 4 states have been fed to lactating cows as the only

source of energy for periods of from 2 to 5 months after which part of the hay was replaced by a concentrate. The net energy values of the various feeds were calculated on the basis of the chemical analyses of the feed stuffs and in some cases on the basis of digestion trials. In only 2 cases out of 25 did the actual milk production of the cows on all alfalfa hay rations fall below the expected milk production. In fact the actual milk production of the cows was so close to the expected milk production as to suggest that the net energy values of hays may be estimated by the feeding of hay alone to cows until milk production and body weight are fairly constant. Replacing part of the hay with corn, sucrose plus starch, or sucrose plus starch plus cellulose (10–10–80) did not produce any changes in milk production which could not be explained on the basis of the calculated net energy intake. However, the replacement of part of the hay with dried corn distillers' solubles resulted in some increases in excess of the expected milk production. It is possible that dried corn distillers' solubles may improve digestibility when added to an all alfalfa hay ration. Further explorations with distillers' solubles are needed.

THE EFFECT OF PASTURE ON RATE AND EFFICIENCY OF GAIN AND ON CARCASSES OF SWINE FULL-FED AND FED 80 AND 60 PERCENT OF A FULL-FEED. H. J. Smith, J. W. Cole, C. S. Hobbs, J. A. Erwing, E. J. Chapman and J. B. McLaren, *Tennessee Agricultural Experiment Station.*

Studies involving full and limited feeding on pasture with and without protein supplement have been conducted at the Knoxville and Columbia Stations with a variety of pastures. A total of 188 pigs including Hampshires, Hampshire-Duroc crossbreds and Landrocs were fed in Spring 1949 and Winter 1950 experiments. Lots in all treatments were duplicated with a minimum of 3 pigs per lot. Feed intake of limited-fed pigs was regulated on the basis of a percentage of body weight. Results for the Knoxville and Columbia experiments for Spring 1949 show that the pigs (av. initial wt. 80 lbs.) in the following lots, full-fed drylot, full-fed pasture, 80% of a full feed on pasture and 60% of a full feed on pasture made average daily gains of 1.56, 1.62, 1.40 and 1.18 pounds, and consumed 432, 373, 340, and 314 pounds of feed per 100 pounds of gain respectively. Pigs (av. initial wt. 57 lbs.) in the Winter 1950 Columbia experiment with grain sorghum as the chief grain concentrate made average daily gains of 1.62, 1.55, 1.50 and 1.26 pounds, and had feed requirements of 411, 368, 296, and 264 pounds respectively. Heavier pigs (av. initial wt. 110 lbs.) in the Winter 1950 Knoxville experiment made daily gains of 1.77, 1.85, 1.61, and 1.47 pounds and had feed requirements of 419, 398, 318, and 256 pounds respectively. Complete carcass data were obtained on all pigs. Backfat thickness of carcasses in full-fed lots was greater than in limited-fed lots. Carcasses from full-fed lots graded slightly higher according to U.S.D.A. proposed standards than those in limited-fed lots but full-fed lots had a higher percentage of excessively fat carcasses. Carcasses of pigs fed 60% of a full feed on pasture were lacking somewhat in quality while 80% of full feed lots produced an acceptable type of carcass.

NUTRITIONAL REQUIREMENTS OF EWES WINTERED UNDER RANGE CONDITIONS. J. L. Van Horn, Wm. H. Burkett, G. F. Payne, G. C. Hughes, and F. S. Willson, *Montana Agricultural Experiment Station.*

One thousand grade ewes were divided by age, weight and type of breeding, into four groups after breeding season. All ewes were plainly marked for group identification to facilitate separation into four pens each morning with a cutting chute. After separation, each group received ½ pound per head of pelleted concentrates. The pellets were custom-milled to specifications and had the following protein contents: Group I, 10.4%; Group II, 18.2%; Group III, 27.1%; Group IV, 37.0%. Calcium content of the pellets was equalized and they were fortified with phosphorus, trace minerals, and vitamin A. After feeding, all ewes were grazed as one band to eliminate differences in grazing conditions among the groups. Samples of the range forage were taken periodically through the experimental grazing period which lasted from January 5 to March 27, 1949. The sheep on the higher levels of protein pellets maintained their weight better than those on the lower levels. There was very little difference

in the grease fleece weights. The lambs born from the ewes on the higher protein levels were slightly heavier at birth, however, the weaning weights were practically the same. The net returns per ewe were greater for the group on the third highest level (27.1%). Part of this difference was due to more twins being born in that group. This project was planned for a duration of four years.

Physiology Section

J. F. Sykes, *Chairman*

THE EFFECT OF HORMONES ON THE GROWTH AND FATTENING OF YEARLING STEERS. F. N. Andrews, W. M. Beeson and F. D. Johnson, *Purdue University.*

Eight lots of five yearling Hereford steers each were fed a fattening ration of corn-and-cob meal, cottonseed meal, molasses feed, clover-timothy hay, bonemeal and salt for 182 days. Four treatments were used in duplicate: (1) control, (2) 60 mg. of stilbestrol pellets subcutaneously, (3) 120 mg. of stilbestrol pellets subcutaneously, (4) 180 mg. of testosterone pellets subcutaneously. The average daily gains of the control steers were 2.24 lb. daily. The stilbestrol groups 2 and 3 gained 2.47 and 2.68 lb. daily. The testosterone treated steers, group 4, gained 2.18 lb. per day. There were marked differences in the feed required per unit of gain. The controls required 707 lb. of concentrates per 100 lb. of gain. The cattle in groups 2 and 3 required 676 and 624 lb. of concentrates per 100 lb. of gain, respectively, and those in group 4 required 713 lb. of concentrates. Hay consumption per unit of gain was likewise reduced in the stilbestrol treated steers. Testosterone did not improve growth rate or feed efficiency in the steers. There was no significant difference in the carcass grades of the four groups of steers.

CORRELATION BETWEEN VARIOUS TESTS OF SEMEN QUALITY AND BULL FERTILITY. P. J. Buckner & E. L. Willett, *American Foundation for the Study of Genetics.*

The values of methylene blue, sperm numbers, initial motility, storage at 4° C. in yolk-citrate-sulfanilamide (YCS) and in 3% aniline blue solution, incubation at 45° C. in YCS, and pH during incubation at 37° C. in YCS and in 0.9% NaCl as tests of semen fertility have been determined by correlating them with 60–90 day non-returns. All of these tests were made on each of 65 collections from 12 bulls. A collection consisted of semen from two or more ejaculates mixed together. The non-returns were based upon a range of 33 to 309 and an average of 103 services per collection. Total, within-bull and between-bull correlation coefficients were calculated, and the highest values were obtained with the latter. The calculation of multiple correlation coefficients (R's) for between bulls using a combination of tests gave values high enough to enable fairly accurate prediction of fertility. For example, R for pH of fresh semen in NaCl (A), methylene blue reduction time (B), sperm per cc. of fresh semen (C), initial progressive motility (D), total motility after two days storage at 4° C. (E) and drop in progressive motility in aniline blue during storage for 120 minutes at 4° C. (F), and non-returns (X) is 0.87. This coefficient is not significant, however, probably because of the small number of degrees of freedom. $R_{BDFX}=0.85$, which is significant at the 5% level of probability. Additional studies to include more bulls should be conducted to establish definitely the reliability of such tests for measuring semen and bull fertility. Possibly the addition or substitution of other tests would result in higher correlations.

APPLICATION OF THE IBERIA HEAT TOLERANCE TEST TO SWINE. J. L. Fletcher, *Mississippi Experiment Station.*

Modifications of the Iberia Heat Tolerance Test were applied to a group of Duroc and Poland China pigs. These modified tests involved the exposure to direct sunlight for periods of 15 minutes and 30 minutes. Tolerance coefficients were calculated for each exposure period by the formula devised by Rhoad and by the modification of this formula suggested by Gaalas. Coefficients based upon 30-minute exposure were lower than those based upon 15-minute

exposure. Coefficients calculated by the Gaalas formula gave a wider spread for individuals. There was a highly significant positive correlation between coefficients determined by the two methods. There were highly significant differences between the Duroc and Poland pigs and between barrows and gilts in heat tolerance coefficients.

THE EFFECTS OF ENVIRONMENTAL TEMPERATURE AND RELATIVE HUMIDITY ON THE ACCLIMATION OF CATTLE IN THE TROPICS. C. Gaztambide Arrillaga, R. C. Miller and W. L. Henning, *The Pennsylvania Agricultural Experiment Station and The University of Puerto Rico.*

A two-year study was conducted with 134 head of cattle representing five dairy and three beef breeds in herds located in different climatic areas of Puerto Rico under conditions with a mean environmental temperature of $84.6 \pm 0.22°$ F. and relative humidity of 63.8 ± 0.53 percent. The data were analyzed using an abbreviated Doolittle method based on Laplace's development of a determinant. The effect of an increase of 1° F. or 1% relative humidity in the environmental conditions on the body temperature, respiratory rate, pulse rate, blood hemoglobin and milk production was calculated by this method. Body temperatures for both dairy and beef cattle under these conditions exceeded an assumed normal body temperature of 101.5° F. by approximately one-half degree F. Higher than normal respiratory rates indicated increased respiration as a means of maintaining a normal body temperature within certain limits. The pulse rates of all individuals tested were approximately normal. Low blood hemoglobin values of the order of 6.9 mg. per 100 ml. of blood were not associated with climatic factors but may reflect possible nutritional deficiency. An analysis of variance for milk production showed significant breed differences and possible seasonal differences with higher milk production accompanying lower winter temperatures. It is concluded that with respect to acclimation of dairy cattle, environmental temperature is more important than relative humidity, while the latter plays a more significant role with beef cattle. Jersey and Brahman grade cattle showed the best adaptability to climatic factors.

STUDIES ON THE ENDOMETRIAL CUPS OF THE PREGNANT MARE. H. H. Cole, T. M. Clegg and J. M. Boda, *University of California.*

Further studies indicate that these interesting structures are concerned with endocrine and exocrine secretion of gonadotrophin. The specific cells concerned with the secretion of the hormone appear to be the epithelial cells lining the uterine glands in the cup area. During their early period of functioning, most of the hormone is passed into the blood stream. In other words, the cups are functioning as an endocrine organ. Later, the gonadotrophin is secreted into the lumens of the uterine glands; these glands are now exocrine in function. Eventually, gonadotrophin and other secretory products of the uterine glands accumulate between the allantochorion and the endometrium. This causes the formation of allantochorionic pouches which remain, in some instances at least, until the fetus has a crown-rump measurement of 35 cm.

THE RELATIONSHIP OF MOTILITY RATING UNDER STORAGE FOR SIX DAYS AT 38° F. TO THE FERTILIZING CAPACITY OF BULL SEMEN. M. H. Ehlers and R. E. Erb, *State College of Washington.*

Fertility of bovine semen samples as represented by percent 60 to 90-day non-returns was compared to motility at time of collection, and to motility at daily intervals during storage through 6 days. The maximum motility rating was 10 and samples in storage were maintained in yolk-phosphate buffer refrigerated at 38° F. Most inseminations were made within 2 days following collection. The study included 7,421 first and second service inseminations from 275 collections of 18 Holstein, Guernsey and Jersey sires. For statistical analyses only those samples (187 qualified) used in inseminating 20 or more cows were included. The correlation between initial motility and non-returns was not significant with the numbers involved (± 0.138). The correlations between motilities during storage and non-returns were highly significant (1 day: ± 0.205; 2 day: ± 0.335; 3 day: ± 0.335; 4 day: ± 0.317; 5 day: ± 0.306;

6 day: ±0.291). Holstein samples generally maintained higher motilities during storage in this study, and none of the correlations with non-returns were significant. A maximum Guernsey correlation between motility and fertility of ±0.561 was obtained on 4 day storage. With Jersey semen the highest correlation of ±0.501 was obtained on semen of 2 day storage. Analysis of variance showed highly significant differences between bulls and between the motility ratings. The per cent non-returns for samples rating 10, 8, 6, 4 and 2 or less on 2 day storage was 63.4, 56.2, 50.3, 49.9 and 39.9 percent, respectively. Similar non-returns for corresponding motilities on 3 day storage were 62.8, 58.3, 52.0, 51.1 and 42.2 percent. The average non-return for all breedings was 55.9 percent. The ability of semen to maintain motility during storage up to 6 days was adjudged a better criterion of fertilizing capacity than initial motility.

ATROPINE BLOCKAGE OF OVULATION IN THE COW AND ITS POSSIBLE SIGNIFICANCE. W. Hansel and G. W. Trimberger, *Cornell University.*

In order to determine the effect of atropine on ovulation in the cow, the time elapsing between the beginning of estrus and rupture of the ovarian follicle was compared during a normal estrous cycle, and during a subsequent estrous cycle in which atropine was administered at the beginning of estrus. Five grade heifers were used, and the time of ovulation was determined by rectal palpation. The atropine sulfate was dissolved in 0.9% saline and given subcutaneously. The dosages used ranged from 37.5 to 65.7 mg./Kg. of body weight, given over a 24-hr. period. Ovulation was delayed for from 20 to 66 hours by the administration of atropine. In general, ovulation did not occur until the atropine symptoms had begun to diminish. Estrus was usually terminated within 4 hours after administration of the drug. In some cases the heifers came in estrus several times within a 2-week period after atropine administration. This experiment, and others in progress, suggest the presence of a neural link in the mechanism controlling the release of luteinizing hormone and ovulation in the cow.

NUTRITIONAL REQUIREMENTS IN HYPERTHYROIDISM. M. H. Magrabi and C. W. Turner, *University of Missouri.*

Inducing hyperthyroidism by feeding thyroprotein has been widely used in animal nutrition. Evidence for the need of additional nutrients in hyperthyroidism has been accumulating in the literature. Work is in progress using different B-vitamins, APF, liver extracts and a number of nutritional supplements containing antibiotics and vitamin B_{12} in the feed of hyperthyroid growing chicks. A level of .04% of thyroprotein (Protamone), twice that recommended for practical use, was incorporated in the feed for 6–9 weeks. APF (.5%) prevented any loss of weight which resulted from feeding the high level of thyroprotein alone. Chicks receiving thyroprotein plus APF had a higher average weight than those receiving either thyroprotein alone or control feed. A higher level of APF (1%) was no more beneficial. Also, a comparison was made between the effects of APF, Vitamin B_{12}, all the B-vitamins, and B-vitamins plus APF plus thyroprotein. Substituting any of these substances for APF did not constitute an improvement during a 9-week period. Thyroprotein and liver residue (5%) gave a better growth rate than when either substance was fed alone. When APF was added with liver extract, the average body weight of the chicks was heavier than those fed liver alone. Experiments using antibiotics and lower levels of thyroprotein with added nutritional supplements are in progress and will be presented.

EFFECTS OF VITAMIN B_{12} ON HORMONAL ACTIVITY. Joseph Meites, *Michigan State College.*

It has recently been demonstrated that growth-inhibition in rats and mice by excessive thyroid administration can be counteracted by feeding vitamin B_{12}. Studies underway in this laboratory indicate that vitamin B_{12} can also partially or completely nullify the growth-inhibiting effects of thiouracil or diethylstilbestrol in rats or mice without inhibiting certain specific tissue responses to these hormones. When vitamin B_{12} was fed together with thiouracil to young rats for 30 days, the vitamin completely overcame the growth-inhibiting action of

the drug but did not prevent thiouracil from inducing hypothyroidism. When vitamin B_{12} was fed together with diethylstilbestrol to young male rats, the vitamin partially overcame the growth-stasis induced by the estrogen but failed completely to prevent the reduction in testis size by the estrogen. Similarly, it was found that B_{12} could counteract the growth-inhibition induced by feeding excessive amounts of thyroprotein to young male rats without overcoming the decrease in testis weight elicited by the latter. These studies suggest that feeding extra amounts of vitamin B_{12} may be beneficial when administering thyroprotein, thiouracil or diethylstilbestrol to animals, since the deleterious effects on body weight could be counteracted without preventing certain desirable systemic effects.

THYROPROTEIN FEEDING OF EWES STIMULATES GROWTH OF THE NURSING LAMB. A. L. Neumann, H. B. Patton and Warren Gifford, *University of Arkansas.*

Lambs, nursing ewes fed 1 gram of thyroprotein (Protomone) per 100 pounds of body weight daily, significantly outgained a control group of lambs whose dams received a similar but unsupplemented ration. Twenty purebred ewes of three different breeds and their 25 lambs were semi-randomly allotted into a control and an experimental group on the basis of the lamb weights. A basal ration of yellow corn, wheat bran, cottonseed meal, and Lespedeza hay was fed separately to both groups of ewes and lambs on the basis of body weight. The thyroprotein supplement fed to the experimental group of ewes was included in the diet and was not accessible to the lambs. Hop clover and oats pasture was available to all animals. The initial and final mean weights of the lambs after eight weeks were as follows, for the control and experimental group respectively: 47.1, 73.5; 47.8, 78.2 pounds ($P<0.05$). Initial and final mean weights of the control and experimental groups of ewes were 149.8, 160.0; 151.1, 155.8 pounds respectively, ($P<0.05$). This significant difference in ewe weights is deemed an advantage for thyroprotein feeding in the case of lactating ewes as contrasted to the same situation in dairy cattle because often nursing ewes tend to get too fat if pastures are excellent in the latter part of the nursing period. Wool growth as determined by measurement of a shoulder patch at the beginning and end of the eight weeks trial revealed no significant measurable difference.

THE USE OF PROGESTERONE IN THE SYNCHRONIZATION OF THE ESTRUAL PERIODS IN A GROUP OF EWES AND THE EFFECT ON THEIR SUBSEQUENT LAMBING RECORDS. C. C. O'Mary, A. L. Pope and L. E. Casida, *University of Wisconsin.*

The effects of 10 mg. progesterone daily for 14 days on synchronization of estrual periods of ewes during the breeding season and on subsequent lambing percentage was studied in a controlled experiment involving thirty-nine ewes. Seventy percent of the injected ewes came into heat on the third day after the end of treatment and the average time at which they were bred was 3.7 days after end of treatment, standard deviation 1.7 days. In the control group the average time of breeding was 9.2 days from the beginning of their breeding period, standard deviation 5.1 days. The standard deviation of the lambing period was reduced in the progesterone treated group to 1.9 days as compared to 5.7 days in the control group. No difference in the fertility of the two groups was demonstrated since the percentage of ewes lambing was 78.9 of the control group and 80.0 of the treated group, and the number of lambs born was 20 in the former group and 19 in the latter.

THE EFFECT OF CERTAIN STEROID HORMONES ON THE GROWTH, FATTENING, AND CARCASS QUALITY OF HEAVY LAMBS. A. L. Pope, C. C. O'Mary, W. E. Batterman, R. W. Bray and L. E. Casida, *University of Wisconsin.*

Two hundred western black-face lambs, averaging 76 pounds were divided into 20 lots, 10 animals per lot. As there were 100 lambs of each sex, the wether and ewe lambs were kept separate to test sex differences. The design of the experiment required 2 lots of each sex for each of the following groups: (1) Controls, (2) diethylstilbestrol (one 15 mg. pellet per animal), (3) testosterone propionate (one 15 mg. pellet per animal) and (4) progesterone (two 30 mg.

pellets per animal). Two additional lots of wethers were treated with both diethylstilbestrol and testosterone propionate and 2 additional lots of ewes with diethylstilbestrol and progesterone. All pellets were implanted subcutaneously. Each lamb was continued on experiment to approximately 100 pounds live weight. The following characteristics were studied: (1) rate of gain (2) economy of gain, (3) carcass grade, (4) degree of finish (5) weight of external fat, (6) weight of internal fat, (7) thickness of external fat, and (8) moisture, fat and ash content of meat. All lambs receiving diethylstilbestrol either alone or in combination with other treatments made more rapid gains than the controls, and required significantly less feed per pound of gain. Their carcass grades were lower and their carcasses carried significantly less finish than the controls. Wethers of the diethylstilbestrol group had significantly less external fat than similarly treated ewes. No significant differences between the controls and either the testosterone propionate or progesterone groups were found for any of the characteristics studied.

PROGESTERONE IN THE MAINTENANCE OF PREGNANCY IN DAIRY HEIFERS. J. I. Raeside and C. W. Turner, *University of Missouri.*

In dairy heifers an attempt to determine the amount of progesterone required for the maintenance of pregnancy has been initiated. Daily subcutaneous injections of 25 mg. of progesterone in olive oil were commenced one day prior to the removal of the corpus luteum by manual expression through a flank incision in the early stages of pregnancy. The operation was performed on the 44th, 48th, and 76th day in the gestation of three Holstein heifers. The fetuses were recovered at abortions 6, 16 and 12 days after the respective corpus luteum had been removed. The administration of 50 mg. of progesterone per day was attended by considerably more success in the maintenance of pregnancy. Two out of four heifers were carrying a live fetus at mid-term, having received the treatment for approximately 100 days. In the remaining two animals resorption presumably had taken place some time after the second month of pregnancy. It would appear that at grossly deficient levels of progesterone, abortion intervenes, while at levels only slightly subnormal, there is a tendency for interruption of pregnancy through resorption, at least in the first half of gestation. Those heifers in which progesterone injections were discontinued came into heat within 4 days of the end of treatment.

THE INFLUENCE OF THE LENGTH OF THE MILKING INTERVAL ON LACTATIONAL BUTTERFAT PERCENT. Ralph P. Reece. *New Jersey Agricultural Experiment Station.*

Records were obtained from the Advanced Registry Office of the Holstein-Friesian Association of America on 109 cows that had completed two A. R. records, one on 3X milking and one on 4X milking. When the two records on the same cow were not of the same length, the longer of the two records was reduced to the length of the shorter one. Of the 109 comparisons the fat test was the same in 12 instances. On 4X milking the fat test was 0.1 percent higher in 18 cases, 0.2 percent in 16, 0.3 percent in 8, 0.4 percent in 5, and 0.5 percent higher in one instance for a total of 48 times. On 3X milking the fat test was 0.1 percent higher in 21 cases, 0.2 percent in 12, 0.3 percent in 11, 0.4 percent in 2, and 0.5 percent in 3 instances for a total of 49 times. It would thus seem that the length of the milking interval has no influence on the lactational butterfat percent.

A STUDY OF PUBERTY AND RELATED PHENOMENA IN CHESTER WHITE AND POLAND CHINA GILTS. G. L. Robertson, R. H. Grummer and L. E. Casida, *University of Wisconsin.*

Thirty-seven Poland China and forty-nine Chester White gilts were checked for heat daily with a vasectomized boar. Average ages at puberty were not significantly different, being 201 days for Poland China and 204 days for Chester White gilts. Poland Chinas weighed an average of 224 pounds at puberty as compared to 212 pounds for Chester Whites. This difference was significant. Average length of the first estrual cycle in Poland Chinas was 21.0

days with a standard deviation of .94 day, while in Chester Whites it was 20.5 days with a standard deviation of 1.48 days. The difference in variability was highly significant. Twenty-seven Chester Whites and sixteen Poland Chinas were bred on the first day of the second estrus and slaughtered 24–48 hours after end of estrus to determine ovulation rates at first and second heats, and fertilization rates at second heat. Differences in ovulation rates between breeds were highly significant. The average increase of second ovulation over the first (1.6 eggs in Chester Whites and 1.2 eggs in Poland Chinas) was highly significant. The difference between breeds in average fertilization rates at second heat was highly significant, the average being 98.1% for Chester Whites and 92.6 for Poland China gilts. Average size of litters farrowed by the remaining 22 Chester White gilts was 10.27 and for the 21 Poland Chinas was 6.48. Estimates of embryonic death were 25% for Chester White and 36% for Poland China gilts. Gilts which were farrowed later in the season tended to reach puberty at a younger age.

THE HORMONE CONTENT OF PITUITARIES OF CYCLING SWINE. G. E. Robinson, Jr. and A. V. Nalbandov, *University of Illinois.*

The object of this study was to measure the changes in the gonadotrophic and thyrotrophic activity of normal swine pituitaries during the 21-day estrual cycle and to correlate these changes with the changes occurring in the ovaries. There is a significant correlation between the rise and fall in gonadotrophic hormone (GTH) and the rise and fall in the number of ovarian follicles ($r=0.69$, $p=0.01$). Follioular size changes independently of the GTH content. The GTH potency is lowest when the females are in heat (days 1 and 2 of cycle) and when only a few follicles, all of which are of ovulatory size, are present. These correlations and other considerations lead to the conclusion that so far as the GTH is concerned the bio-assay of the pituitary actually reflects the rate at which this hormone is being secreted and utilized by the ovary. There is an increase in the amount of thyrotrophic hormone secreted during the cycle ($r=0.42$), a questionable association between this hormone and the rate of GTH secretion ($r=0.33$, $p=0.06$) and no association between the thyrotrophic hormone and the events in the ovaries. There is no change in the weight of the pituitary during the cycle and no association between its weight and the rate of hormone secretion. A total of 33 pituitaries obtained from females killed at appropriate intervals during the entire estrual cycle were assayed individually. The increases in testes and thyroid weights of baby chicks were endpoints used for the determination of the two hormones.

CHARACTERISTICS OF THE HAIR COAT OF BRAHMAN AND JERSEY CATTLE AS FACTORS IN HEAT TOLERANCE. Robert R. Shrode and Thomas C. Cartwright, *Texas A. & M. College.*

Sampling techniques were devised to estimate various characteristics of the hair coat of 30 Brahman and 30 Jersey cattle. The characteristics studied were: average number of hairs per unit area of skin, average hair length and average hair diameter. Highly significant differences were found between the Brahmans and Jerseys for number and length. The Brahmans were estimated to have an average of 1,775 hairs and the Jerseys an average of 1,095 hairs per sq.-cm. skin area. Average hair length of the Brahmans was estimated to be 3.6 mm. and that of the Jerseys 5.1 mm. Average hair diameter was estimated to be 54.2 and 56.1 microns for the Brahmans and Jerseys, respectively. Highly significant differences among animals of the same breed were observed with respect to all three of the hair-coat characteristics studied. The index of heat tolerance studied was an average of five respiratory rate determinations on each animal taken on five different days, the respiratory rates of all animals being determined under pasture conditions in the shortest period possible on each day. Differences between breeds and among animals of the same breed were highly significant. The estimate of repeatability of these respiratory rate determinations was 0.72. The only significant correlations observed in each breed were those between respiratory rate and number of hairs per unit of skin area, the estimates being -0.68 and -0.72 for the Brahmans and Jerseys, re-

spectively. It was concluded that density of hair coat may be useful as an indicator of heat tolerance.

FACTORS AFFECTING LITTER SIZE DURING EARLY PREGNANCY IN CERTAIN STRAINS OF SWINE AND THEIR CROSSES. C. D. Squiers, G. E. Dickerson and D. T. Mayer, *University of Missouri.*

Ovulation rate, percentage of ova fertilized and early embryonic mortality were studied in relation to level of inbreeding, age, growth rate, and genetic differences between and within strains, to evaluate sources of variation in litter size. Females from two inbred lines of Polands (II and VI), one of Hampshires (V), non-inbred Durocs and their six crosses were used. Females were bred once at first observed estrus and slaughtered at 24 hours or 25 days post-estrus. Ovulation rate averaged 11.4 for 277 gilts at mean age of 225 days. Recovery of ova was 80 percent. Among gilts having any ova cleaved, 95 percent were fertilized. Total mortality to 25 days averaged 35 percent for gilts. This included 23 percent very early mortality and 7 percent partially decomposed embryos. Mortality was also 35 percent in sows, but only 5 percent were regressive embryos. Crosses averaged 1.2 more ova shed, 1.8 more pigs per litter and .8 fewer pigs lost to 25 days compared with parental inbreds. Both ovulation rate and embryonic mortality were related to age in gilts, together accounting for an increase of .5 pig for 10 days increased age at breeding. Rapid growth of gilts to 5 months was associated with higher ovulation rate and less mortality of ova. The degree of hereditary determination of ovulation rate in the population sampled does not appear to be high, but maternal influence is strongly suggested.

EFFECTS OF ADDED PROGESTERONE UPON EARLY EMBRYONIC DEVELOPMENT AND CONTINUED CORPUS LUTEUM FUNCTION. L. C. Ulberg and L. E. Casida, *University of Wisconsin.*

The effects of daily injections of 2 mg. of progesterone were studied on forty pregnant rabbits. All animals received nine daily subcutaneous injections of 0.5 cc. corn oil, starting about 24 hours after mating. However, the interval of the hormone injections varied between the four equal groups. Each group received one of the following treatments: (1) no hormone, acted as control; (2) 8 mg. of progesterone, divided into 4 injections, started 1 day after mating; (3) same as group 2 except injections were started 6 days after mating and (4) 18 mg. hormone, divided into 9 injections started 1 day after mating. Fifteen days after mating the rabbits were killed and the condition of the embryos and the ovaries was studied. The amount of embryonic death or the growth rate of the embryos in females receiving the hormone did not differ significantly from that in the control females. There was no indication that this amount of progesterone had any effect on the corpora lutea, as indicated by their number or size at the time of slaughter. Also, the function of the corpora lutea was not greatly disturbed as shown by their ability to maintain the pregnancy after the cessation of hormone injections.

CHANGES IN THE VENOUS BLOOD AND URINARY LEVELS OF POTASSIUM, CALCIUM, SODIUM AND CHLORIDES IN DAIRY COWS AT THE TIME OF PARTURITION. Gerald M. Ward, M. F. Adams and T. H. Blosser, *Stage College of Washington.*

The blood level and urinary excretion of potassium, calcium, sodium and chlorides were determined in four cows at the time of parturition. Urine collections were made on approximately the 30th, 15th, and 10th days prepartum and for five consecutive days prior to and for five days following parturition and on the 10th, 15th, and 30th days postpartum. Two of the cows developed milk fever, one of them having five recurrent attacks. Potassium values on whole blood ranged from 30.1 to 78.5 mg.% and were rather consistent for individual cows. The cows developing milk fever showed a typical sudden drop in blood calcium, while the cows which did not develop milk fever exhibited a drop, but of less magnitude. The range

of sodium values was 161 to 290 mg.% with most of the values falling between 215 and 250 mg.%. There were no marked differences in whole blood sodium between normal and milk fever cows. Blood chlorides ranged from 307.9 to 424.7 mg.% with no apparent differences between milk fever and normal cows. The daily excretion of potassium in the urine was from 41.95 to 245.98 grams per day. The excretion of potassium at parturition was somewhat lower for all cows. Urinary excretion of calcium reached a low level in all cows on the day prior to calving, followed by a substantial increase on the day of parturition, and a gradual return to normal. The urinary excretion of calcium ranged from .0862 to 2.144 grams per day. Urinary sodium excretion ranged from 0.323 to 19.044 grams per day, with no differences in levels between milk fever and normal cows. Excretion of urinary chlorides ranged from 2.116 to 54.006 grams per day.

CAUSES OF VARIATION IN PUBERTY PHENOMENA IN INBRED SWINE. E. L. Wiggins, A. C. Warnick. L. E. Casida, R. H. Grummer and A. B. Chapman, *University of Wisconsin.*

Data on age at puberty, ovulation rates at different heat periods and litter sizes farrowed by gilts conceiving at different heat periods were obtained on 205 inbred gilts of Chester White and Yorkshire ancestry. Data on age at puberty were obtained on 136 boars from the same herd. The average ages at puberty in the gilts were 236 days in 1948 and 251 days in 1949. Line and year differences in age at puberty were significant. In boars the average ages at puberty were 187 days in 1948 and 203 days in 1949. Line differences were significant in 1948 but not in 1949. Within lines there was a significant tendency for the heavier pigs at 56 and 154 days to reach puberty first but the lines having the heaviest average 154 day weights tended to be the slowest to reach puberty. There was an average increase of 0.8 egg in ovulation rate at second heat in 48 gilts in which the number of eggs ovulated at both first and second heat could be determined. Line differences in ovulation rate were significant. Gilts conceiving at their third heat period farrowed 1.4 pigs more than those conceiving at their second heat and 2.5 pigs more than those conceiving at their puberal heat. These differences approached significance. The average of the fertilization rates (unweighted mean) in 63 gilts bred within 24 hours after the onset of estrus was 82%.

BACTERIA IN DAIRY BULL SEMEN AND THEIR RELATION TO FERTILITY. Szu-Hsiae Wu, Paul R. Elliker, and Fred F. McKenzie, *Oregon Stage College.*

Thirty-seven species of bacteria have been isolated from 225 ejaculates of bovine semen (Guernsey, Holstein, and Jersey) which were qualified for artificial insemination based on their motility rating (9 or above). A few samples occasionally yielded strains of Streptomyces and yeasts. It was found that species of *Micrococcus* and *Pseudomonas* were present in the majority of the samples studied while only one of the 19 bulls had species of *Streptococcus* in its semen. The bacterial plate count showed marked differences between samples from different bulls and between different ejaculates of the same bull. The count varied from none to 29,700 per ml. of undiluted fresh semen with an average of 684. The regression of the non-return rate 8 months after artificial insemination (5,743 cows bred) on the plate count indicated that semen with a high bacterial count may be associated with poor breeding results. There is an indication, based on the difference between the 2 and 8-month non-return rates, that *M. aurantiacus*, *M. pyogenes* var. *albus*, and *E. coli* may be associated with prenatal death. Results also suggested that *M. aurantiacus*, *A. metalcaligenes* and *C. simplex* may be associated with low fertility. *Pseudomonas aeruginosa* occurred frequently in the semen of both high and low fertility bulls.

NEWS AND NOTES

The forty-second annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, Illinois on November 24 and 25, 1950, with a dinner for the honored guest on November 26. Abstracts of all submitted papers which are to be presented at the meeting are published in this issue of the JOURNAL OF ANIMAL SCIENCE. Reprints of the Abstract Section of this issue of the JOURNAL will be available to members at the annual meeting.

The nominating committee of the American Society of Animal Production with Paul Gerlaugh as Chairman has prepared the following slate of officers for consideration by the Society at its annual business meeting in Chicago on November 25:

For President--
E. W. Crampton
Macdonald College, Canada
For Vice-President
H. M. Briggs
University of Wyoming
For Secretary-Treasurer
A. J. Dyer
University of Missouri
J. I. Miller
Cornell University

S. H. Work was in Honduras during August consulting on Animal Husbandry problems for the United Fruit Company.

An Institute of Genetics has been established at the Ohio State University. Members of the Institute represent various departments including Animal Science (Experiment Station), Dairy Husbandry, Poultry Husbandry, and Veterinary Preventive Medicine.

The European Association for Animal Production held a study meeting at the University of Ghent on October 11 dealing with the "Incidence of Hormones and Their Importance for Animal Production."

C. J. Watson, Head of Animal Nutrition, Division of Chemistry, Department of Agriculture, Ottawa, Canada, Died August 25.

A. B. Caine, who had been a member of the Animal Husbandry Department at Iowa State College for 34 years, died suddenly on August 13 at Mesa, Arizona.

W. C. Skelly, of the Animal Husbandry Staff, Rutgers University, died September 14.

John O. Williams, long-time horse husbandman with the Animal Husbandry Division, U.S.D.A. and some years retired, died suddenly at Falls Church, Virginia, on September 24, 1950.

T. J. Cunha was made Head of the Department of Animal Husbandry and Nutrition at the University of Florida effective Oct. 1.

Swine Production is the title of a new text book by W. E. Carrol and J. L. Krider, published by McGraw-Hill Co. The text deals with the establishment and operation of the swine enterprise with emphasis on those breeding, feeding, and management and marketing factors which most affect profits. Utilization is made of recent information on nutrient allowances including tracer minerals and vitamins as recommended by the National Research Council in the formulation of balanced rations and supplements for drylot and pasture feeding.

The Principles of Genetics, by Edmund W. Sinnott, L. C. Dunn, and Th. Dobzhansky, published by McGraw-Hill Co., has appeared in the fourth edition. Additions in the present edition occur in chapters on cytogenetics and chromosomal aberrations, population genetics dealing with genetic equilibrium and race and species formation, and a new chapter on the

nature of gene and gene action. Considerable space is devoted to the use of fungi and such micro-organisms as bacteria, protozoa, and viruses which have lately contributed so substantially to an understanding of genic action.

H. M. Briggs, Secretary-Treasurer of the "Society," resigned his former position with the Oklahoma A & M College and is now Dean of the College of Agriculture and Director of the Agricultural Experiment Station at the University of Wyoming.

L. E. Hanson, of the animal husbandry staff, University of Nebraska, resigned on October 1 to accept a position on the animal husbandry staff, University of Minnesota.

Stanley Terrill has been made head of the swine division, animal science department, University of Illinois, succeeding J. L. Krider, resigned.

T. D. Bell has recently resigned from the Utah State Agricultural College to accept the position vacated by the promotion of Rufus S. Cox at Kansas State College.

Clyde W. Warburton, for many years employed by the USDA as director of extension work, deputy governor of farm credit administration and other positions, died in Washington, D. C. on September 22 at the age of 70.

H. R. Smith, general manager of the National Live Stock Loss Prevention Board since its organization in 1934, and formerly animal husbandry staff member in Corn-Belt Agricultural Colleges, retired July 1, and was succeeded by J. R. Pickard, who will retain headquarters in Chicago.

Peters Hall is a new building on the St. Paul campus of the University of Minnesota, which will house the animal and poultry husbandry departments of the institution. It is named for the late W. H. Peters who headed the staff for many years.

Don S. Bell, of the Ohio Agricultural Experiment Station became secretary of the American Delaine Merino Record Association on April 1, 1950.

Jack B. Taylor, formerly vocational agriculture instructor was made secretary of the American Rambouillet Association, May 1, 1950 with headquarters at San Angelo, Texas.

Fred S. Idtse of the Brown Swiss Association was named president of the National Society of Live Stock Record Associations, at the recent annual meeting in Chicago.

A. D. Weber, of Kansas State College, received the degree of doctor of science at the 94th annual commencement exercises at Purdue University in June.

C. L. Harlan, marketing specialist of the Office of Foreign Agricultural Relations, USDA, is conducting a study of the Canadian livestock industry for the purpose of gathering information indicating future trends in livestock production (particularly cattle) in that country as a basis for forecasting probable movement to this country for the next 5 years.

Lyle V. Springer, Michigan State College graduate and recently in newspaper work, is now executive assistant in the office of the American Aberdeen-Angus Association at Chicago.

Alex McDonald, for many years in charge of beef cattle for the University of California at Davis, is now associated with a land and cattle company at Lonark, California.

Andrew Duffle, animal husbandry graduate, University of Illinois and for 15 years in vocational agricultural work in Oklahoma and Forrest R. McClain, animal husbandry graduate, Oklahoma A & M College, recently on the animal husbandry extension staff Louisiana State University, have been added to the field staff of the American Hereford Association.

Andrew M. Duncombe, animal husbandry graduate, Ohio State University was recently appointed director of publicity for the American Shorthorn Breeders' Association with headquarters in Chicago.

Orville G. Bentley is a new assistant in the department of animal science at the Ohio Agricultural Experiment Station, effective May 1, 1950. He is a graduate of South Dakota State College, 1942, and the University of Wisconsin, 1947.

SUBJECT INDEX FOR VOLUME 9

A

Abstracts—
Papers presented at Forty-Second Annual meeting of the American Society of Animal Production, 634
Age—
Effect on the tenderness of beef, 347
Alfalfa—
Nutritive value, 363
APF—
Effect of supplement on efficiency of feed utilization in swine, 615

B

Bacteria—
Rumen, as affected by roughage and casein in ration, 214
Beef—
Influence of rate of freezing and length of freezer storage upon quality, 13
Tenderness in relation to different muscles and age in the animal, 347
Benzine hexachloride—
Contamination of pork muscle and fat from treated hogs, 112
Biotin—
Supplement for pig rations, 73
Blood—
Proteins of pregnant ewes, 180
Bluegrass—
Nutritive value, 363
Breeding—
Causes of variation in length of gestation in dairy cattle, 593
Cows, relation of carotene content of range forage to their vitamin A requirements, 23
Effect of the plane of nutrition on carcass quality in selected lines of swine, 602
Hereditary aspect of eye cancer in Hereford cattle, 578
Occurrence of estrus and ovulation in postpartum sows, 66
Relationship between certain body measurements and carcass characteristics in swine, 37
Repeatability of progeny performance records in Hereford sires, 588
Revised estimates of heritability of economic characteristics in beef cattle, 582
Breeding and genetics—
Problems, designs and techniques in investigations, 461
Brome grass—
Nutritive value, 363

C

Cancer—
Heredity in Hereford cattle, 578
Carotene—
Content of range forage in relation to the vitamin A requirement of breeding cows, 23
Effect of processing method of cottonseed meal upon blood content, 560
Effect of sulfaquinoxaline upon its metabolism in dairy calves, 314
Cattle—
Alfalfa hay and digestion of ground corncobs, 207
Causes of variation in length of gestation, 593
Comparative value of hay and corn silage for wintering beef cows, 243
Comparative values of hydraulic, expeller and solvent processed oilmeals for steers, 194
Deposition and excretion of phosphorus-32 on high molybdenum and copper diets, 552
Digestibilities of distillers dark grains from malt and from fungal amylase fermentations, 20
Effect of diethylstilbestrol dipropionate upon postpartum changes in the cow, 238
Effect of forage composition on its nutritive value when cut and fed green, 531
Effect of processing method of cottonseed meal upon blood constituents, 560
Effect of ration upon constituents of blood, 545
Effect of stilbestrol, testosterone, thyroid alteration and spaying on growth and fattening of heifers, 321
Effect of sulfaquinoxaline in dairy calves, 314
Estimates of heritability of economic characteristics, 582

Extension of record of performance in bee production, 335
Factors influencing birth and weaning weights of beef calves, 338
Forage consumption as related to chemical composition and nutritive value, 354
Hereditary aspect of eye cancer in Hereford cattle, 578
Influence of casein in ration upon roughage digestion, 214
Influence of feeding thiouracil to dairy bull calves, 571
Influence of shows upon beef production, 331
Methods of separation of urine from feces, 565
Milk from cows fed toxic cottonseed meal, 201
Relation of carotene content of range forage to the vitamin A requirement of breeding cows, 23
Relation of the post-partum breeding interval to reproductive efficiency in the dairy cow, 307
Repeatability of performance of Hereford sires as measured by progeny records, 588
Tenderness of beef in relation to different muscles and age in the animal, 347
Cecum—
Motility patterns in the horse, 261
Chlorine—
Content of feed stuffs, 153
Requirements of growing pigs, 300
Cobalt—
Deficiency in New York State, 221
Effect of B-Vitamins upon deficiency in the sheep, 484
Effect on the synthesis of vitamin B_{12} in sheep, 414
Function in nutrition of sheep, 404
Copper—
Effect upon phosphorus deposition and excretion in steers, 552
Cottonseed meal—
Effect of processing method on blood content of carotene, vitamin A, and fat in cows, 560

D

Digestibility—
Magnitude of certain sources of variability in data, 504
Of distillers dark grains from malt and from amylase fermentation by steers, 20
Of pasture forage, protein as an indicator, 231
Value of average data, 373
Digestion—
Of cellulose by rumen microorganisms as influenced by grains and protein-rich feeds, 523
Of cellulose in good and poor quality roughages, 513
Of ground corncobs as affected by feeding alfalfa hay, 207

E

Ergostanyl acetate—
Supplement for pig rations, 73
Estrus—
Occurrence in postpartum sows, 66

F

Fat—
Effect of processing method of cottonseed meal upon blood content in cows, 560
Feeding—
Creep feeding of nursing pigs, 157
Feeds—
Sodium, potassium and chlorine contents, 153
Fertility—
Effect of progesterone treatment on subsequent lambing records in the ewe, 499
Folic acid—
Supplement for pig rations, 73
Forage—
Effects of its composition on nutritive value, 531
Protein as an indicator of pasture digestibility, 231
Sulfur dioxide preservation of grass silage, 540

G

Grazing—
Effect of vitamin A supplementation on reproduction of ewes on the range, 446
Growth—
Role of manganese for swine, 170
Synthetic rations for swine, 163

Growth and fattening—
Alfalfa and alfalfa-brome grass hays for lambs, 491
Comparison of high and low protein corn for swine, 625
Effect of aureomycin and meat and meat and bone scraps in swine, 608
Effect of methyl thiouracil and thiouracil in swine, 54
Effect of stilbestrol in lambs, 383
Effect of stilbestrol in suckling lambs, 380
Effect of thiouracil upon carcass composition and nitrogen balance in swine, 58
Effect of thyroprotein in swine, 48
Effect of vitamin B_{12} in the pig, 90
Fish solubles and liquid fish for swine, 94
Growth factors—
Supplements to a corn-soybean oil meal ration for weanling pigs, 281

H

Hemoglobin—
Effect of sulfaquinoxaline in young dairy calves, 314
Heritability—
Revised estimates for economic characteristics in beef cattle, 582
Hormones—
Effects of diethylstilbestrol dipropionate upon postpartum changes in the cow, 238
Testosterone propionate and thyroprotein for rams, 186
Horse—
B-vitamin content of skeletal muscle, 139
Compressed feeds, 255
Effect of egg yolk upon sperm, 143
Motility patterns of the cecum, 261

I

Inositol—
Supplement for pig rations, 73
Investigations—
Animal—problems, techniques and experimental designs, 461

L

Lactation—
Role of manganese for swine, 170
Lysine—
Supplement for pig rations, 73

M

Manganese—
In swine nutrition, 170
Meat—
Contamination from hogs treated with benzene hexachloride, 112
Effect of salt, pepper and sage upon the stability of ground pork stored at zero degrees fahrenheit, 30
Effect of thiouracil upon carcass composition in swine, 58
Effect of thyroprotein on carcass composition of swine, 48
Influence of rate of freezing and length of freezer-storage upon quality of beef, 13
Problems, techniques and experimental designs in investigations, 461
Relationship of carcass characteristics to body measurements in swine, 37
Tenderness of beef in relation to different muscles and age in the animal, 347
Methyl thiouracil—
Effect in the rations of lambs and aged ewes, 3
Effect in swine, 54
Milk—
From cows fed toxic cottonseed meal, effects upon rats, 201
Milk production—
Role of manganese for swine, 170
Molybdenum—
Effect upon phosphorus deposition and excretion in steers, 552

N

Nutrition—
Function of cobalt in sheep, 404
Problems, techniques and experimental designs in investigations, 461

O

Orchard grass—
Nutritive value, 363
Ovulation—
Occurrence in postpartum sows, 66

P

Pantothenic acid—
Deficiency in weanling pigs, 78
Observations on deficiency in swine, 619
Pasture—
For growing-fattening pigs, 289

Grazing as related to chemical composition and nutritive value of forage, 354
Problems, techniques and experimental designs in investigations, 461
Protein as indicator of its digestibility, 231
Relative nutritive value of Kentucky bluegrass, timothy, brome grass, orchard grass and alfalfa, 363
Performance—
The extension of record of performance in beef cattle, 335
Phosphorus—
Deposition and excretion by steers on high molybdenum and copper diets, 552
Minimum requirement for equilibrium in the lamb, 426
Physiology—
Problems, techniques and experimental designs in investigations, 461
Pork—
Effect of thyroprotein on carcass composition of swine, 48
Ground, effect of salt, pepper, and sage upon its stability when stored at zero degrees fahrenheit, 30
Relation of carcass characteristics to body measurements in swine, 37
Potassium—
Content of feed stuffs, 153
Requirements of growing pigs, 300
Proceedings of the forty-first annual meeting of the American Society of Animal Production, 115
President's address, 115
Minutes—
of the forty-first business meeting, summary of, 119
Memorials
William Henry Black, 125
George Haines, 125
Arthur Henry Kuhlman, 126
Robert Frederick Miller, 126
Walter H. Peters, 127
W. E. Sewell, 127
Honor guest for 1949, 129
Index of—
committee chairmen for 1950, 134
program chairmen for 1950, 134
official representative for 1950, 134
Morrison—
award for 1949
The American Feed Manufacturers' Association—
award for 1949, 133
Progesterone—
Use in synchronization of estrual periods in ewes, 499
Protein—
As an indicator of pasture forage digestibility, 231
Comparison of high and low content in corn for growing-fattening pigs, 625

R

Rations—
APF supplements for weanling pigs, 281
Baby pig, requirement for vitamin B_{12} when fed as a concentrate, 90
Casein effects upon roughage digestion in cattle, 214
Comparative value of hydraulic, expeller and solvent processed oilmeals, 194
Comparative value of mixed hay and corn silage, 243
Compressed feeds for horses, 255
Containing methyl thiouracil for lambs and aged ewes, 3
Digestibilities of distillers dark grains from malt and from fungal amylase fermentations, 20
Effect of alfalfa hay upon digestion of ground corncobs, 207
Effect of thyroprotein on growth and carcass composition of swine, 48
Effect on blood constituents in cattle, 545
Effect on blood proteins of pregnant ewes, 180
Expeller vs. solvent soybean meal, 176
Fish distillery and fermentation by-products in the drylot rations of weanling pigs, 101
Low in vitamin B, effect on skeletal muscle of horse, 139
Pantothenic acid deficiency in weanling pigs, 78
Pig, effect of vitamin B_{12}, 90
Sodium, chlorine, and potassium requirements of growing pigs, 300
Supplemented with folic acid, lysine, inositol, biotin, and ergostanyl acetate for the young pig, 73
Supplements and pastures for growing-fattening pigs, 289
Swine, containing fish solubles and liquid fish, 94
Swine, containing methyl thiouracil and thiouracil, 54
Synthetic, for swine, 163
Value of refuse screenings, 7

Reproduction—
Causes of variation in length of gestation period in dairy cattle, 593
Effect of season of birth on sexual development in gilts, 277
Effect of diethylstilbestrol dipropionate upon postpartum changes in the cow, 238
Effect of purified diets and pantothenic acid deficiency in swine, 619
Effect of testosterone propionate and thyroprotein in rams, 186
Incidence of female genital abnormalities in swine, 269
Relation of post-partum breeding interval to reproductive efficiency in the dairy cow, 307
Role of manganese for swine, 170
Synthetic rations for swine, 163
Riboflavin—
Deficiency in the lamb, 420
Roughage—
Alfalfa and alfalfa-brome grass hays for growing and fattening lambs, 491
Cellulose digestion in good and poor quality roughages, 513
Comparative value of mixed hay and corn silage, 243
Digestion as affected by casein in ration of cattle, 214
Rumen—
Digestion of cellulose as influenced by grains and protein-rich feeds, 523
Effect of cobalt on the synthesis of vitamin B_{12} in sheep, 414
Ruminants—
Comparative values of hydraulic, expeller and solvent processed oilmeals, 194

S

Season—
Effect on sexual development in gilts, 277
Sheep—
Alfalfa and alfalfa-brome grass hays for growing and fattening lambs, 491
B-vitamins in relation to cobalt deficiency, 484
Blood proteins of pregnant ewes, 180
Cobalt deficiency in New York State, 221
Comparative values of hydraulic, expeller and solvent processes oilmeals for lambs, 194
Effect of cobalt on the synthesis of vitamin B_{12} in the rumen, 414
Effect of feeding concentrates to range ewes on lamb and wool productivity, 431
Effect of forage composition on its nutritive value when cut and fed green, 531
Effect of methyl thiouracil in ration, 3
Effect of stilbestrol on fattening lambs, 383
Effect of stilbestrol on the growth rate in suckling lambs, 380
Effect of testosterone propionate and thyroprotein in rams, 186
Effect of thiouracil, 387
Effect of vitamin A supplementation on reproduction on the range, 446
Feeding value of Norghum sorghum when fed to lambs, 495
Function of cobalt in nutrition, 404
Intake of grazed forage in relation to chemical composition and nutritive value, 354
Minimum phosphorus requirement for phosphorus equilibrium, 416
Riboflavin deficiency in the lamb, 420
Use of progesterone for controlling estrual periods, 499
Value of refuse screenings in ration, 7
Shows—
Effect upon productive values in beef cattle, 331
Silage—
Sulphur dioxide preservation of grass, 540
Sodium—
Content of feed stuffs, 153
Requirements of growing pigs, 300
Solubles—
Fish and liquid fish for growing and fattening swine, 94
Fish distillery and fermentation by-products for weanling pigs, 101
Sorghum—
Feeding value when fed to lambs, 495
Spaying—
Effect upon growth and fattening in heifers, 321
Sperm—
Effects of egg yolk upon detrimental physical and chemical factors, 143
Stilbestrol—
Effect in fattening lambs, 383
Effect on growth and fattening in heifers, 321
Effect on growth rate of suckling lambs, 380
Swine—
Adequacy of synthetic rations, 163
APF supplements to a corn-soybean oil

meal ration for weanling pigs, 281
Choline vs. betaine in their nutrition, 176
Contamination of pork muscle and fat in animals treated with benzene hexachloride, 112
Creep feeding of nursing pigs, 157
Dried whole aureomycin mash and meat and bone scraps for growing-fattening pigs, 608
Effect of APF supplement upon efficiency of feed utilization, 615
Effect of fish solubles and liquid fish in the ration, 94
Effect of methyl thiouracil and thiouracil, 54
Effect of season of birth on sexual development in gilts, 277
Effect of thiouracil upon carcass composition and nitrogen balance, 58
Effect of thyroprotein on growth and carcass composition, 48
Effect of vitamin B_{12} on the growing pig, 90
Expeller vs. solvent soybean meal in feeding, 176
Fish distillery and fermentation by-products in the drylot rations of weanling pigs, 101
High and low protein corn for growth and fattening, 625
Inadequacy of purified diets for reproduction and effects of added deficiency of pantothenic acid, 619
Incidence of female genital abnormalities, 269
Manganese for growth, reproduction and lactation, 170
Occurrence of estrus and ovulation in postpartum sows, 66
Pantothenic acid deficiency in weanling pigs, 78
Pastures and supplements for growing-fattening pigs, 289
Plane of nutrition effects on carcass quality, 602
Relationship between certain body measurements and carcass characteristics, 37
Requirement of the baby pig for vitamin B_{12} fed as a concentrate, 83
Sodium, chlorine, and potassium requirements of growing pigs, 300
Supplementing rations with folic acid, lysine, inositol, biotin, and ergostanyl acetate for the young pig, 73
Symposium—
Problems, techniques and experimental designs in animal investigations, 461

T

Testosterone—
Effect on growth and fattening in heifers, 321
Thiouracil—
Effect in swine, 54
Effect on dairy bull calves, 571
Effect on sheep, 387
Effect upon carcass composition and nitrogen balance of swine, 58
Thyroid—
Effect of alteration on growth and fattening of heifers, 321
Thyroprotein—
Effect on growth and carcass composition, 48
Timothy—
Nutritive value, 363

V

Vitamin A—
Effect of processing method of cottonseed meal upon blood content in cows, 560
Effect of sulfaquinoxaline upon its metabolism in dairy calves, 314
Effect of supplementation on reproduction of ewes grazed on green and dry summer ranges, 446
Requirement of breeding cows in relation to carotene content of forage, 23
Vitamin B—
Deficient ration and effect on skeletal muscle of horse, 139
Relation to cobalt deficiency in sheep, 484
Vitamin B_{12}—
Effect of cobalt on synthesis in the rumen of sheep, 414
Effect on the growing pig, 90
Requirement of the baby pig, 83

W

Weights—
Factors influencing the birth and weaning weights of beef calves, 338

AUTHOR INDEX FOR VOLUME 9

A

Anderson, Gerald C., 163
Andrews, F. N., 48, 321, 387
Ashworth, U. S., 7

B

Baker, Marvel L., 338
Barrick, E. R., 387, 565
Barron, G. P., 363
Becker, D. E., 221
Beeson, K. C., 221, 404
Beeson, W. M., 48, 94, 321, 387
Benson, R. H., 615
Bentley, O. G., 170
Bethke, R. M., 207, 214, 513, 523
Black, W. G., 186
Blakeslee, L. H., 420
Blosser, T. H., 7
Blunn, Cecil T., 338
Bogart, Ralph, 143
Bohstedt, G., 112, 153, 170, 300, 414, 484
Bolin, D. W., 180
Bolin, F. M.,180
Brady, D. E., 461
Bray, R. W., 112
Briggs, H. M., 194, 426
Brugman, H. H., 602
Buchanan, M. L., 180
Burnside, J. E., 615
Burroughs, Wise, 207, 214, 513, 523
Butler, O. D., Jr., 30

C

Carroll, F. D., 139
Carroll, W. E., 58, 157
Casida, L. E., 66, 186, 238, 269, 277, 461, 499, 593
Catron, D. V., 608
Chapman, A. B., 593
Cipolloni, Mary Ann, 373
Clark, R. T., 582, 588
Colby, R. W., 73, 90, 446, 560, 619
Cowan, R. L., 363
Crampton, E. W., 461
Culbertson, C. C., 608
Culik, R., 420
Cunha, T. J., 73, 446, 615, 619
Cupps, P. T., 261

D

Darlow, A. E., 331
Darroch, J. G., 431
Davis, G. K., 552
Dickerson, G. E., 461
Dinusson, W. E., 321, 380
Dobbins, F. A., 625
Drown, Donald, 20
Dyer, I. A., 176, 281

E

Earle, I. P., 255
Earley, E. B., 625
Edwards, H. M., 615
Ellis, G. H., 404
Ensminger, M. E., 90, 619

F

Fairbanks, B. W., 157
Forbes, R. M., 20, 231, 354, 531

G

Gall, L. S., 214
Gallup, Willis D., 194, 426
Garrigus, W. P., 354, 531
Gerlaugh, Paul, 207, 214, 513, 523
Geurin, H. B., 94
Glasscock, R. S., 615
Gregory, Keith E., 338
Grose, E. G., 363
Grummer, R. H., 66, 112, 153, 170, 269, 277, 300
Grunert, R. R., 153

H

Hale, W. H., 414, 484
Hamilton, T. S., 58, 625
Hankins, O. G., 37, 347
Hansard, S. L., 565
Hatfield, E. E., 194
Hathaway, I. L., 571
Hazel, L. N., 461
Headley, H. G., 513
Hetzer, H. O., 37
Hickman, C. W., 491
Hiner, R. L., 347
Hobbs, C. S., 565
Hodgskiss, H. W., 73, 619
Hoefer, J. A., 94
Hogan, Albert G., 163
Howell, C. E., 261

I

Ingram, R. H., 363

J

Jafar, S. M., 593
James, Marian F., 83
Johnson, B. Conner, 83
Jordan, R. M., 380, 383, 495

K

Keener, H. A., 404
Keith, T. B., 491
King, J. X., 37
Klosterman, Earle W., 180
Knapp, B., Jr., 578, 582
Knodt, C. B., 314, 540
Knox, J. H., 23
Krider, J. L., 58, 83, 101, 157, 176, 281, 289, 625

L

Lepley, K. C., 608
Loeffel, W. J., 571
Long, John, 523
Loosli, J. K., 221
Lucas, Henry L., 373, 504
Luecke, R. W., 78, 420

M

MacVicar, R. W., 545
Maddy, H. K., 363
Mayer, Dennis T., 143
McMillen, W. N., 78
Meadows, G. B., 615
Meyer, J. H., 153, 300
Miller, J. I., 13, 243
Morrison, F. B., 243
Muir, Joseph, 335

N

Nelson, R. H., 420
Neumann, A. L., 83
Nordskog, A. W., 431

O

O'Mary, C. C., 499
Owens, R. D., 552

P

Parham, A. P., 560
Pavlech, Helen M., 373
Pearson, A. M., 13, 615
Percival, G. P., 404
Perry, T. W., 48
Phillips, P. H., 153, 170, 300, 414, 484
Poling, C. E., 201
Pope, A. L., 186, 414, 484, 499

R

Rasmussen, R. D., 73
Reece, Ralph P., 3, 54
Riggs, J. K., 560
Ronning, Magnar, 314
Ross, O. B., 545
Ruegamer, W. R., 201

S

Salisbury, G. W., 307
Schick, A. L., 186
Schneider, Burch H., 373, 504
Schultze, A. B., 571
Scott, G. W., Jr., 7
Shaw, A. O., 7
Shirley, Ray L., 552
Skelley, William C., 3, 54
Smith, Sedgwick E., 221
Stark, R. H., 491
Swift, R. W., 363

T

Terrill, S. W., 58, 101, 157, 281, 289, 625
Thiersch, J. B., 83
Thorp, F., Jr., 78, 420

V

Van Arsdell, W. J., 545
VanDemark, N. L., 307
Vander Noot, George W., 3, 54
Van Horn, J. L., 431

W

Warnick, A. C., 66
Warwick, E. J., 446
Washko, J. B., 363
Watkins, W. E., 23
Wiggins, E. L., 277, 269
Wisnicky, W., 238
Woodward, R. R., 578, 588

Z

Zeller, J. H., 37

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should contain a clear statement of the purpose of the investigation and its relation to other work in the same field, but long reviews should be avoided. Concise presentation of data is desired. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results, or their relation to some problem of the livestock industry. Each paper should end with a brief summary outlining the points proved in the investigation and their application, or their relation to a livestock problem.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, *i.e.*, Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. Literature cited lists should be typed in the style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as is feasible.

5. A maximum of eight pages per paper will be published without charge. Overrun in excess of this amount will be charged to the author or his institution at current publication costs. This restriction does not apply to invited review papers. The cost of making engravings, in excess of one page per paper and of printing tables in excess of two pages per paper, will also be charged to the author or his institution.

6. Authors will receive galley proof of articles, together with a reprint order form and a form for supplying an abstract for "Biological Abstracts." *Corrected proof, reprint order and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.* Institutional orders for reprints should be made out to the American Society of Animal Production.

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. L. E. Casida, Department of Genetics, University of Wisconsin, Madison, Wisconsin.

12. All correspondence concerning subscriptions to the JOURNAL and other business matters should be addressed to the Business Manager of the JOURNAL, Dr. H. M. Briggs, University of Wyoming, Laramie, Wyoming.